The Use of Palynofacies Analysis in Archaeopalynology

Andrew William Hoaen

PhD.
University of Edinburgh
1999

Dedication

Dedicated to my wonderful wife Helen and son Jack, for help and forbearance.

Declaration

I hereby declare that this is all mine own work

Acknowledgements

There are too many people to thank for their kindness and encouragement along the way. The list starts with my birth family and ends with my own family. Taking in along the way my supervisors Dr. Geraint Coles and Prof. Ian Ralston to whom many thanks for helping me wrestle first with the research for this difficult topic and secondly for helping me make sense of that research. Thanks also to the support staff at Edinburgh, including Pat Storey and Ian Morrison, and to all the other members of staff who helped especially Dr. Trevor Watkins and Dr. Paula Milburn.

Away from the Department help with case studies came from Terry O'Connor at the University of Bradford and Richard Bradley at the University of Reading, and many thanks are due particularly to Richard Bradley for help with access to prepublication drafts of the excavations at Clava cairns. Help with fungal spores came from Dr. Bas van Geel at the Hugo Vries Institute at Amsterdam and many thanks are due to him and his students.

My adoptive family the Loney's also helped with large measures of excellent vintage red wine from the family plot, and more practically with computer support and equipment.

Finally, I must thank Dr. Helen Loney for helping along the way who in the course of my PhD. managed to finish her own and produce a son Jack who provides equal measures of inspiration and exasperation.

Abstract

Palynofacies analysis expands traditional archaeopalynology by including not only pollen, but also fungal spores, algal microfossils and a variety of microfossil debris. Archaeopalynology is the study of past human environments through pollen analysis. By using palynofacies assemblages in archaeopalynology it is expected that greater detail and understanding of past environments will be obtained than by conventional pollen analytical methods.

Within archaeopalynology, several different approaches are used to obtain environmental information; these include examining the pollen of modern analogues of past environments, archaeological deposits and buried soils, peat and lake sediments. To test whether palynofacies analysis was a appropriate method to use in archaeopalynology a case study in each of the three areas outlined above was carried out.

The first case study investigated the palynofacies assemblages associated with a modern upland sheep pen and the surrounding pasture, located in the Meldon Hills, near Peebles. The result of this study was the discovery that a greater degree of environmental variation was present in the overall palynofacies assemblages than was present in the pollen data alone. Some of the environmental variation between samples was linked to the presence of fungal spores with a preference for animal dung. This suggested that the presence of certain fungal spores in the archaeological record may be indicators of herbivore dung.

Buried soils and archaeological deposits associated with the Clava cairns at Balnuaran, near Inverness, formed the second case study. The palynofacies analysis resulted in a greater understanding of the taphonomy of the deposits and the palaeoenvironments at the excavated sites than would have been available through more conventional pollen work.

Palynofacies investigation of cultural landscape development of a small basin at South Nesting, Shetland formed the third case study. The analysis demonstrated that changes in the palynofacies assemblages of the deposits, was the result of both anthropogenic change and autecological changes.

These three case studies all demonstrated that analysis of the total content of a palynological preparation, can contain important information relating to past human environments.

Table of Contents

List of Figures

List of Tables

Chapter One: Introduction

Introduction

One strand of current research in palaeoecological and archaeological studies is the exploration and adaptation of new and novel techniques of environmental analysis, such as DNA analysis (MacHugh *et al.* 1999), organic residue analysis (Jones 1997) and fungal spore analysis (Clarke 1994), to name but three. The reason for this interest in methodological and technical innovation is the often incomplete and unsatisfactory nature of environmental reconstructions based on conventional analytical techniques. One important technique used for the study of both vegetation history and the evolution of cultural landscapes is pollen analysis. Pollen analysis is also used in the analysis of buried soils and archaeological deposits to obtain information relating to both the environment and the economy of past human societies. The research in this thesis addresses two common problems in the interpretation of pollen sequences in archaeological and cultural landscape studies. The first of these is how to relate the local environmental conditions at the point of deposition to the recovered pollen assemblage. The second is the limited number of pollen taxa that signify anthropogenic activity in the landscape. This thesis is concerned with a new approach to environmental reconstruction which uses pollen and other microfossils to provide information relating both to the local environment of deposition and to past anthropogenic activity.

This chapter sets out a definition of palynofacies analysis, and discusses the principal aims and objective of the thesis. Subsequent chapters are organised into two themes: the first theme (Chapters 2-3) comprises a theoretical and methodological introduction to palynofacies analysis. In the second theme (Chapters 4-6), each case study is dealt with in a self contained Chapter which gives the background to the study, the results and discussion. There is a concluding chapter which discusses the nature of palynofacies analysis in archaeopalynology. A series of Appendices complete the thesis, which detail preparation and microfossil classification methods used (Appendix 1), the microfossil catalogue (Appendix 6) and photographs of the various microfossils identified during the analysis as well as photographs of the various case study areas (Appendix 5).

Palynofacies analysis

Palynofacies analysis is a type of palynological study originally developed in pre-Quaternary palynology. It involves the integration of a number of palaeoecological techniques used to describe the organic-walled microfossil component of a sediment. The principal technique employed in palynofacies research is that of pollen and cryptogram spore analysis augmented by the study of other organic-walled non-pollen microfossils principally fungal spores, *incertae cedis* microfossils, algal microfossils and palynodebris[1]. A review of the various techniques that go to make up palynofacies analysis as used in this thesis is outlined in the second half of Chapter 2.

Palynofacies analysis in archaeopalynology

The origins of palynofacies analysis in palaeopalynology[2]

This thesis involves the use of the facies concept in the analysis of sediments, in this case the palynofacies concept (Combaz 1964). A facies is a set of distinctive biological or physical characteristics that define a particular sediment. A distinctive biological component of a sediment is known as a biofacies: a palynofacies is therefore a particular type of biofacies (Brenchley 1990). Palynofacies analysis was originally developed to help understand the origin of marine sediments, where the major determinants of the palynofacies assemblage are water transport and gravity (Batten 1982, Muller 1959, Traverse 1988). A review of the theory and development of palynofacies analysis in pre-Quaternary geology forms the first section of Chapter 2. In pre-Quaternary geology, a sedimentary model of the origin of palynofacies assemblages based on the long-distance transport of terrestrial materials to the point of deposition has been developed (Traverse 1988). For terrestrial sediments the sedimentary model for the deposition of palynofacies assemblages needs to be replaced by one which takes into account the contribution of *in-situ* deposition and of local environmental change (Van Geel 1986,

---

[1]palynodebris are the acid insoluble fragments of plants, insects, fungi and decay products found in palynological preparations.

[2] Palaeopalynology may be defined as the study of pollen and cryptogram spores derived from indurated and semi-indurated sediments. As such it represents a branch of palynology concerned largely with environmental reconstruction during the pre-Quaternary period. (Traverse 1988)

Clarke 1994). Thus a new model of palynofacies assemblages in terrestrial sediments based on research by Van Geel (1978, 1986), Clarke (1994) and using an environmental model is developed in this thesis (see below). Such a technique should have many applications in archaeopalynology. Archaeopalynology is a term adapted from the French used by Fægri and Iversen to describe palynological research on archaeological sites or in cultural landscape studies (1989)

Aims and objectives

The aim of this research is to test the hypothesis that the palynofacies analysis of sediments can provide further information about local environmental conditions and thereby augment conventional pollen analytical studies. Research, principally by van Geel (1978) and Clarke (1994), has shown that fungal spores and other organic walled non-pollen microfossils are principally derived from the local environment of a terrestrially formed deposit such as a peat, soil or a archaeological deposit. By combining the analysis of non-pollen and pollen microfossils in archaeopalynological studies the final aim is to better understand past environments.

The study is primarily concerned with developing and testing an environmental model of palynofacies analysis for archaeological and other sediments. The thesis has focused on the analysis of fossil material, which almost by definition has the most potential to demonstrate the usefulness of the technique to archaeopalynology. The research did not therefore develop the investigation of the taphonomy, dispersal and identification to species of the form taxa, except where these could be inferred from the fossil assemblage, because of the limited time available.

This research had three interlinked objectives:

1) to examine whether fossil palynofacies assemblages can provide interpretable environmental information

2) to determine whether fossil palynofacies assemblages are indicators of macro- and micro- environmental spatial variation

3) to ascertain whether changes in fossil palynofacies assemblages are associated with non-local environmental change (vegetational or anthropogenic change)

Macro environmental variation is used here in the same sense as

Birks (1986) to signify environmental change of several thousands of years affecting areas of several square kilometres. Micro-environmental change following Birks (1986) relates to environmental change over short time scales and small areas c. 2-300 square metres for pollen data. In this thesis micro-environmental variation principally refers to geographical variation between samples across smaller areas between 1 metre square to 2-300 metres square.

Point 2 relates to identifying variations in the frequencies of the components of a palynofacies assemblage between closely spaced samples (micro-environmental variation), and between larger vegetation units e.g. differences between mixed oak forest and heathland for example. Point 3 relates to whether gross environmental changes such as result from climate forcing or anthropogenic change will be recorded particularly in the non-pollen microfossil record.

A number of methodologies were used to analyse archaeological and natural sediments (see Chapter 3). Three studies were selected to accomplish the objectives of the research: a modern environment and two fossil case studies were undertaken (Fig. 1.1). The case study of modern palynofacies distributions took place in the Meldon Hills, near Peebles and compared palynofacies assemblages from heavily dunged areas of the landscape with less intensively dunged areas (Chapter 5). The second case study examined fossil palynofacies distributions, from the burial cairns at Balnuaran of Clava, near Inverness. In this study the analysis of a number of buried soil profiles from four monuments was conducted to assess the variation in palynofacies assemblages, both within a monument and between monuments of apparently similar date and close geographical proximity (Chapter 6). The second archaeological study was of a sequence of lake and peat sediments from a small basin adjacent to a number of known archaeological sites at Trowie Loch, Shetland. This analysis was designed to assess the effects that human or other environmental changes may have had on palynofacies assemblages (Chapter 7).

The final chapter of the thesis is an assessment of the degree to which the research achieved its overall aim and met the objectives set above (Chapter 8). The methods used for the analysis of fossil material are presented in Appendices, as is a catalogue of the non-pollen and cryptogram spore microfossils encountered during the analysis.

An environmental model of palynofacies assemblages

Palynofacies analysis was originally developed by palaeopalynologists to provide stratigraphic information and palaeoenvironmental reconstructions of pre-Quaternary marine sediments. The following discussion sets out the justification for the adoption of a palynofacies approach in the study of terrestrial archaeological and other natural sediments. It puts forward the arguments for adopting a palynofacies approach in palaeoenvironmental analysis of Quaternary studies whilst laying out the technical difficulties that exist with the analysis of non -pollen microfossils. A theoretical model of the origins of palynofacies assemblage in terrestrial sediments is also created.

Pollen source and taphonomic problems with the conventional approach to archaeopalynology

There are two principal reasons to develop a palynofacies approach in the study of pollen spectra from terrestrial sediments such as buried soils, archaeological deposits and peats: firstly to overcome interpretative difficulties related to the origin of pollen in archaeological deposits and buried soils (see below), and secondly to use non-pollen microfossils as indicators of human and other environmental change.

In the analysis of pollen from archaeological sites, the deposits available for study are frequently small scale, often less than $1m^2$ in area. This constraint affects how pollen is recruited into the deposit. There are few studies of pollen recruitment into small deposits and so it is difficult to interpret the extent to which the pollen spectra reflects the regional and local pollen rain (Fægri and Iversen 1989, Krzywinski *et al* 1983, Andersen 1973, 1988). On archaeological sites there is a further related problem of how to untangle the admixture of air borne pollen, and pollen than may have come from human or animal activities e.g. from animal dung, hay, occupation debris etc. (Berglund 1986).

Most pollen in buried soils appears to derive mostly from local sources within 20-30 m^2 of the site (Dimbleby 1985, Andersen 1973, Aaby 1984). Other studies however, demonstrate that regional pollen may significantly skew the pollen spectra of soils as a result of small local pollen production (*c f.* Vuorela 1972, Hall 1989). Despite the limited nature of studies of pollen recruitment into small areal deposits the work, most modern sam-

pling studies suggests that the majority of pollen in most point samples is derived from vegetation communities within 20-30 m^2 of the sampling point (Andersen 1973, Gaillard *et al.* 1992, Tipping *et al.* 1997). This conclusion may not apply to all vegetation communities: for example, the local pollen production of anthropogenic communities such as cereal fields may be swamped by the regional pollen rain (Vuorela 1972).

By examining the local microfossil spectra from fungi and other organisms sensitive to micro environmental variation the analyst aims to improve the interpretation of pollen assemblages from buried soils and archaeological deposits. In a palynofacies analysis, information relating to the local environment is sought from other microfossils such as fungal spores and fungal hyphae and from the type of palynodebris present in the sediment. An example of where non-pollen microfossils have provided information about the local environment is van Geel's 1988 analysis of early post glacial deposits at Ussello, Holland where the identification of hyphopodia of the fungi *Gaeumannomyces* type was vital to demonstrating the local growth of Cyperaceae (van Geel *et al.* 1988 p. 92).

The taxonomy of pollen grains is such that many can only be identified to genus or family level (Moore, Webb and Collinson 1991 and Birks and Birks 1980). For many environments this limits the palaeoecological interpretation possible because it is not possible to determine the past species that a pollen spectra represents. This is particularly true in cultural landscape studies where a limited number of pollen taxa are reliable and consistent indicators of anthropogenic activity (Behre 1986). A palynofacies approach may thus extend the range of microfossils used to indicate a range of human and natural environments. An archaeological example of the use of fungal spores as anthropogenic indicator species is the identification of the coprophilous fungal spore *Sporoniella* in basin sediments used by Davies to identify the spread of intensive grazing in the western United States in the nineteenth century AD (1987).

However, there are several problems in the analysis of non-pollen microfossils and these will be discussed briefly below.

Problems in the use of discrete non-pollen microfossils (fungi, algae)

A major difficulty with the study of non-pollen microfossils is the

lack of detailed taxonomic information relating to many of the form taxa recovered and identified (Clarke 1994). Nonetheless, Clarke (1994) and van Geel (1978 onwards) have identified a number of indicator species that are associated with particular plants, and/or environmental conditions. In addition van Geel has shown the presence of recurrent associations of fungal spores and vegetation in his studies of raised bogs and lake deposits in the Netherlands (1978). Though Clarke was unable to demonstrate such recurrent assemblages in her studies of modern day anthropogenic environments, she did show that fungal spores in such environments are highly sensitive to local environmental conditions (1994). Fungal spore ecology indicates that whilst there are discrete ecological relationships between fungal spore communities and a variety of environments, there is a degree of heterogeneity within the species that may colonise a particular environment at a particular time (Griffin 1972, Dix and Webster 1995).

The taxonomic limitations of non-pollen microfossils make detailed environmental interpretations difficult. Because of this the analysis may only demonstrate the presence of past environmental differences between assemblages with similar pollen spectra, rather than explain how those differences came about. Many non-pollen microfossil interpretations currently rely on the presence of a few interpretable indicator species (as with pollen analysis) (Clarke 1994), thus limiting the scope of the resulting analysis. It is hoped that, by developing the potential of integrated pollen and microfossil analyses, the taxonomic study of microfossils will be stimulated, and consequently that the number of environmentally interpretable non-pollen microfossils will increase.

A further problem is that of the origins of fungal spores and palynodebris in terrestrial sediments. Both Clarke and van Geel are of the opinion that the majority of fungal spores derive from local production and the results of van Geel's studies of peats and lacustrine sediments suggest that this is indeed the case. Terrestrial fungal spores are only found intermittently in lacustrine sediments compared with the huge numbers that can be recovered from peats and soils (van Geel 1988, van Geel *et al.* 1981, see also Chapter 7 below).

A possible model of the development of palynofacies assemblages in terrestrial sediments

The sedimentary model of palynofacies distributions developed for marine sediments depends on the mechanical sorting of microfossils during transportation (Habib 1979, Traverse 1988). Because of this, such a model is clearly not applicable to the terrestrial sediments analysed in this thesis. As stated above, the work of Tipping and others in relation to pollen deposition and that of van Geel and Clarke for fungal spore deposition indicates that much of the microfossil component of a terrestrial sediment derives from local deposition. The assumption made in this thesis is that for most terrestrial sediments the microfossil assemblage is largely derived from local production, with a lesser proportion attributable to mechanical transport either by animal, wind or water. If this assumption that the palynofacies assemblage in a terrestrial sediment is largely the result of local autochthonous production is sustainable it follows that a model of the origins of the assemblage may be derived from the local environmental conditions (Fig 1.2).

This model relies on integrating information from three discrete groups of biological data, each derived primarily from local production. However, for some sediments such as peats the pollen component of the assemblages may have a large regional component:

1) Pollen and cryptogram spores which may represent both local and regional vegetation (Moore, Webb and Collinson 1991, Galliard *et al.* 1992).

2) Fungal, algal and *incertae cedis* microfossils predominately derived from local production (see van Geel 1978, 1986 and Clarke 1994)

3) Palynodebris likewise indicative of local production.

The procedure for for interpreting the microfossil assemblage identified from the sediment is to group them into local palynofacies assemblage zones (LPfAZ see Chapter 3) which represent the totality of organic walled microfossils within a particular deposit.

The LPfAZ as used in this thesis differ from those used in pre-Quaternary palynology. Often in pre-Quaternary palynology the total assemblage is grouped into broad categories such as pollen, fungal spores etc., with no attempt at differentiating different categories within these groups (Batten 1982, Traverse 1988, Habib 1979). It was considered that such an

approach would not provide sufficiently detailed palaeoenvironmental analysis for the case studies used in this thesis. The approach employed is to identify all of the discrete organic -walled microfossils (fungal spores, pollen etc.) to the lowest taxonomic level practicable. These are then identified where possible to genus or species or are given a type number using the scheme outlined by Clarke (1994).

Conclusion

This chapter has set out the aims and objectives of this research programme. It has introduced the main concepts, especially the idea of the palynofacies as a particular type of biofacies of a sediment. The palynofacies assemblage may then be used to produce a palaeoenvironmental record for a particular sediment. The chapter ended with a justification for the adoption of a palynofacies approach in the study of terrestrial sediments and suggested a model of the deposition of palynofacies assemblages in terrestrial sediments.

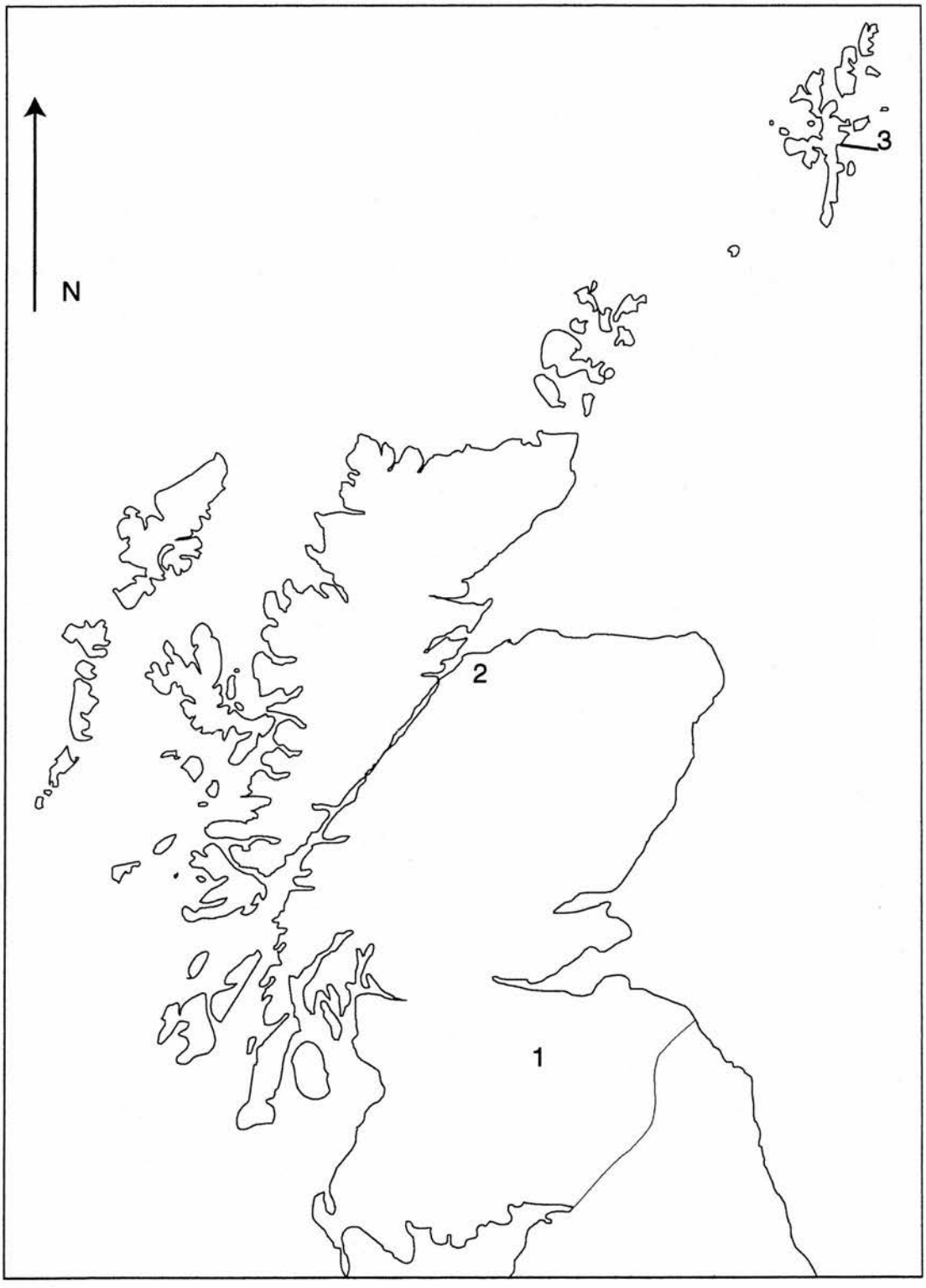


Fig 1.1 Location of case study areas in Scotland 1) Meldon Hills 2) Balnuaran of Clava 3) Trowie Loch

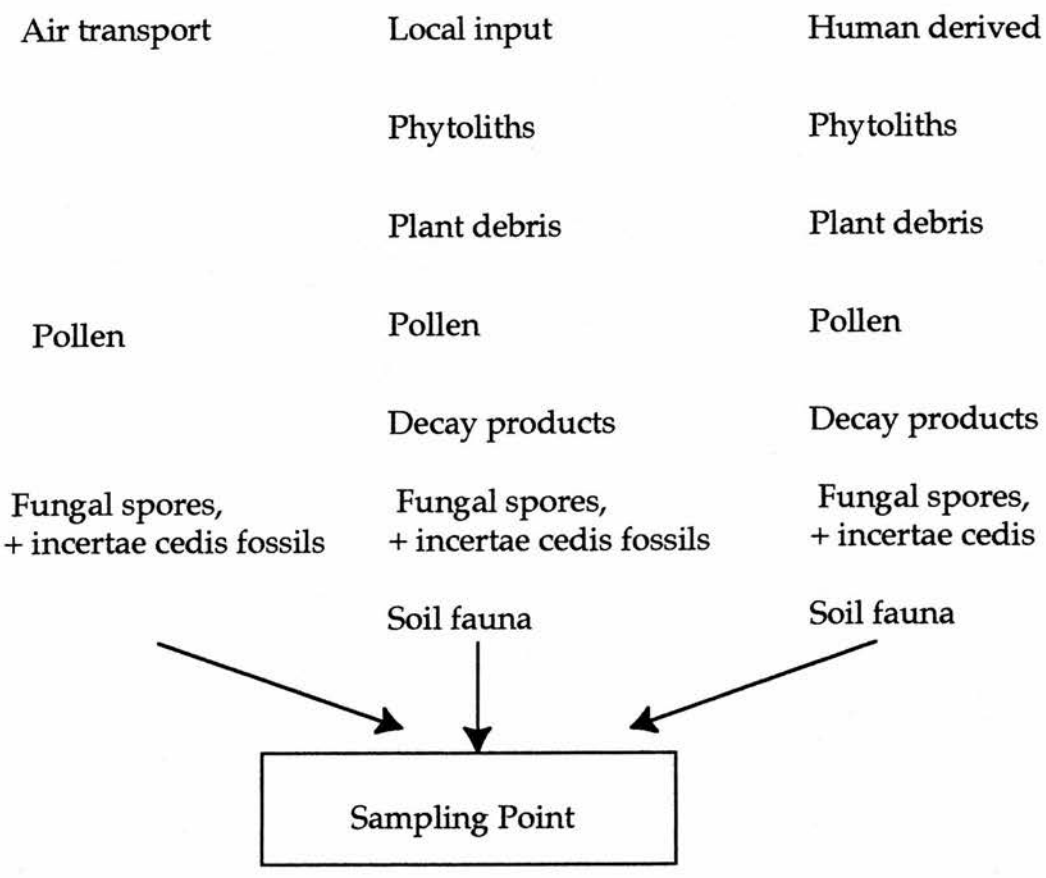


Fig. 1.2 Flowchart of dominant sources of and impacts on palynofacies in a terrestrial sediment

Chapter Two: Review of past work

Introduction

This chapter is a review of work conducted in a number of differing fields related to palynofacies analysis and archaeopalynology. The development of palynofacies techniques in pre-Quaternary and Quaternary geology and palaeoecology is related in this essay to its use in understanding the evolution of marine sedimentary basins. To understand how the palynofacies concept may be applied in the context of archaeopalynology, it is necessary to briefly review the relevant literature from the following fields; pollen and cryptogram spores, fungal spores and *incertae cedis* fossils, fungal hyphae and palynodebris analysis.

The development and application of palynofacies analysis in Pre-Quaternary and Quaternary palynology

Modern day distribution and sedimentation studies of palynomorphs and palynodebris

Palynofacies research is broadly based on the Hoffmeister patent, issued in 1954 (Hoffmeister (1954) in Traverse 1988). Hoffmeister demonstrated that palynomorphs in marine sediments are largely derived from water transportation and the deposition of palynomorphs is controlled largely by mechanical sedimentological factors. Hoffmeister's discovery was of crucial importance to oil exploration as it provided a means of assessing the location of oil and gas deposits within sedimentary deposits. Consequently, most palynofacies studies since 1954 have concentrated upon the marine sedimentary environments that are of most interest to pre-Quaternary geologists and are most likely to contain oil and gas deposits.

The Hoffmeister patent inspired a number of studies of modern day palynofacies assemblages in marine environments (see Cross *et al.* (1966). The classic study of marine palynofacies distributions is that of the sediments of the Orinoco delta and nearby shelf by Muller (1959). Though this research is over thirty years old, the range of microfossils and depositional environments examined is exemplary. Microfossils recorded included not only pollen and spores but also hystrix (dinoflagellates), fungal spores and acritarchs. The microfossil analysis was coupled with an examination of the distribution of a variety of types of palynodebris, cuticle (five categories)

and tracheid fragments. Whilst confirming Hoffmeister's patent statement, Muller's study also demonstrated that other more complex variables e.g. current flow and basin morphology needed to be included in the interpretation of palynomorph and palynodebris distributions. Muller concluded that an analysis of the microfossil and palynodebris content of marine sediments would help in the production of more accurate interpretations of marine palaeoenvironments and sedimentary processes.

From Muller's study and later investigations it appears that palynomorphs and palynodebris particles behave according to the laws governing other similar sized sedimentary particles e.g silt and sand grains in water based systems (summarised in Traverse 1988). However, because of their lower specific gravity, pollen grains tend to settle out at a size range smaller than similarly sized sedimentary particles (Traverse 1988). This leads to most palynomorphs being sedimented in silts and muds.

In water based sedimentary systems, whether fluvial, marine or estuarine, the assemblage of microfossils deposited in sediments will depend on four main factors: 1) the input of palynomorphs and palynodebris from the surrounding vegetation, 2) an input from reworked material eroded during the transport of sediments, 3) the depositional energy and environment of the sediments to be examined, 4) the effect of diagenetic changes to the sediment prior to burial (Traverse 1988).

Development and application of palynofacies analysis in Pre-Quaternary palynology

The term palynofacies first appears to have been used by Combaz (1964) to refer to the total assemblage produced using standard palynological processing techniques (*cf.* Kummel and Raup 1965, Moore, Webb and Collinson 1991). Combaz included single entity sporomorphs (a pollen or spore grain containing sporopollenin), palynomorphs (other discrete entities in the palynological assemblage such as algal colonies) and palynodebris (such as plant fragments) in his analysis of sedimentary rocks.

Batten (1973) later used palynofacies to describe assemblages of microfossils (including spores, cuticle etc) that were associated with specific rock types in the correlation of the stratigraphy of the Wealden (Early Cretaceous of southern England). The three major categories he used to define the assemblage types were: abundance, average size, and the state of

preservation of the microfossils. The use of the assemblage types improved the accuracy of the stratigraphic interpretation and, when integrated with plant megafossil and sedimentological information, gave additional information on the palaeoecology of the sediments. This type of analysis is founded on the assumption that the "relationships between various aspects of organic preparations and sedimentary environments can certainly be determined" (Batten 1982, 108).

One drawback of Batten's analysis of the Wealden was that his assemblage types were largely confined to that particular succession and the assemblage types have little applicability elsewhere. An attempt to widen the scope of palynofacies analyses was that of Habib (1979) who derived a classification of sediments based upon the total component of palynomorphs and palynodebris. Habib attempted to define sediments on the basis of characteristic palynofacies assemblages that reflected the sediments' distance from the shoreline. This is useful in oil exploration as it supplies a quick and cheap method for the rapid assessment of the oil bearing potential of stratigraphic sequences. However, such a method is bound to oversimplify the complex patterns of environmental and sedimentological processes sought by Quaternary palaeoecologists.

Since Batten's pioneering work, the application of palynofacies techniques has grown, particularly in marine palynology and oil exploration. Palynofacies analysis has been employed in defining fossil marine, estuarine and fluvial environments. A typical study is that of Parry *et al.* (1981), in which different marine environments were distinguished on the basis of their palynomorph and kerogen[1] distributions. Palynomorphs were divided into three categories: marine palynomorphs (dinoflagellates, leiospheres, tasmantids, and foraminiferal linings); terrestrial palynomorphs (spores, pollen grains and bisaccate pollen); and fresh water palynomorphs (principally *Botryococcus*). In addition the analysis was supplemented by recording of the kerogen component of the preparation. Kerogen was broken down into five categories: black wood, brown wood, resin, cortex and cuticle. Other data collected included information on the size and preservation of the different components.

---

[1] Kerogen is a term used in petroleum geology to describe disseminated organic matter found in mature sediments. It is thus synonymous with palynodebris in sediments which have undergone little diagenetic change (Cope, M.J. in Batten 1982)

This information was used to identify associations that could be correlated with marine environments. The kerogen and palynomorph composition of the sediments was found to be determined by three main factors; 1) the palynological input to the environment, 2) the depositional energy of the environment, and 3) to post- depositional diagenetic changes within the sediments (Parry *et al.* 1981).

Palynofacies analysis has been demonstrated to be a useful methodology for understanding and distinguishing aquatic sedimentary depositional environments (Traverse 1988, Batten 1982, Cross *et al.* 1966). However, within more complex environments such as estuarine and deltaic systems, the technique appears unable to separate sub-environments because of sediment mixing (Darrell 1973, Farr 1988).

Palynofacies analysis in Quaternary palynology

Palynofacies analysis in the above studies was based on the mechanical sorting of microfossils in marine environments. Although the palynofacies approach has not found favour in Quaternary palaeoenvironmental studies it has to the author's knowledge been explicitly used twice in Quaternary studies once in the study of marine sediments in the Skagerrak near Norway by Manum *et al.* (1985) and once in an archaeological situation by Hunt and Coles (1988). The Skagerrak study is largely descriptive and does not seek to analyze the results to any degree other than noting variation in the samples over time. Hunt and Coles (1988) similarly noted that a range of different microfossils were present in their samples but did not undertake an interpretation of their data. To the authors knowledge no follow up studies using a palynofacies approach in Quaternary studies have subsequently been attempted. Perhaps because other techniques such as diatom analysis are more widely used in the study of Quaternary marine environments, or perhaps because the technique is not widely taught, whatever the reason the palynofacies approach in the study of Quaternary palynology has not been widely adopted.

The above review has dealt with the origins of the palynofacies approach in pre-Quaternary geology. The technique of palynofacies analysis itself comes from the realization that pollen preparations contain many more microfossils than just pollen grains and that these other microfossils may also contain information relating to past environmental change. The next sec-

tion of this chapter is a brief discussion of the main points in the study of the various microfossil groups that make up a pollen preparation.

Pollen analysis

Introduction to pollen analysis

A pollen grain is the container of the male gamete and is produced by both angiosperms and gymnosperms. Pollen grains are the means by which the male gamete is transported to the egg in flowering plants. Cryptogram spores are the resting and dispersal phase of these plants.

The early history and development of pollen analysis is discussed by several authors (e.g Fægri and Iversen 1989) and will not be restated here it being sufficient to note that the term palynology was introduced by Hyde and Williams in 1944 to describe the study of resistant microfossils (Fægri and Iversen 1975). Originally, pollen analysis was concerned with the reconstruction of past vegetation communities by the identification of pollen and spores preserved in peat and lake deposits. Now, however, it is a wide field concerned with the role of pollen and spore grains in such diverse fields as forensic science, archaeology, aerobiology and allergy research.

The underlying principles of pollen analysis are dependent on four main properties of pollen grains:

1) they can be produced in vast quantities

2) they may be extremely resilient

3) Many important taxa are widely and evenly dispersed and can be located away from their original vegetation in lakes and mires

4) they can be retrieved in large quantities from lake and mire sediments

(After Berglund 1986, Birks and Birks 1980, Fægri and Iversen 1989, Moore, Webb, and Collinson 1991)

The above properties of pollen grains have been used to generate a set of assumptions regarding the relationship between pollen grains and the vegetation communities from which they derive. Most important of these assumptions is that pollen from large pollen producers becomes evenly mixed and distributed over the landscape prior to being transported to a suitable environment for sedimentation such as a lake or bog where the

pollen is deposited (Tauber 1965). Pollen recovered from that lake or bog will therefore reflect the composition of the adjacent vegetation over time if samples taken sequentially throughout the vertical profile.

In this thesis the main types of pollen investigative techniques used are soil pollen analysis and off (archaeological) site investigations of the cultural landscape. Both of these are large areas of study and the following review will therefore deal selectively with the key issues within each field.

Soil pollen analysis

The observation of apparent pollen stratigraphies in buried soils by Waterbolk in the Netherlands (1958), Dimbleby in Britain (1962), and others in the 1950's and 60's led to the development of soil pollen analysis. The application of soil pollen analysis to environmental reconstruction is often the only method by which direct information about local vegetation development can be obtained for archaeological investigations (see Dimbleby 1985 for examples). The technique is not, however, straightforward and there are many interpretative difficulties. The following discussion will first outline the main problems with soil pollen analysis before summarizing the two main models for the development of soil pollen stratigraphies, that of Dimbleby (1985) based on constant soil pollen movement due to water perculation and of Andersen based on movement of pollen by soil invertebrates (Andersen 1984).

Two major difficulties with soil pollen analysis analyses are; 1) pollen grains of different ages can be mixed both up and down within a profile, 2) pollen grains are subject to greater degradation in some soils than in peats or lakes, often leading to differential loss of taxa (Dimbleby 1985). Therefore, a key consideration in soil pollen investigations is the type of soil to be analyzed. Those with active soil fauna, such as brown earths, will probably have undergone severe distortion of the pollen spectra, due to mixing, and if they have a high or circum neutral pH then it is highly probable that the pollen will have been destroyed by both chemical and biological degradation. In more acid soils, such as podzols, the acid conditions will tend to retard the activity of soil invertebrates thus reducing the danger of pollen of different ages mixing. The acid conditions will also favour the preservation

[2] Similar conclusions about soil pollen transport were put forward by Munaut (1967) and Guillet (1972) (from Aaby (1984))

of pollen.

The technique of soil pollen analysis is now sufficiently established to have its own text book (Dimbleby 1985), which puts forward a theory for the movement and development of pollen stratigraphies within soils. Dimbleby' s theory of soil pollen incorporation is based on many years of work in the field and was developed largely from practical observation. The theory is based on the concept that pollen is prevented from moving freely within soils by being incorporated into a "humic complex" (Dimbleby 1961 (a), 1961 (b) 1962, 1985). This humic complex slows the incorporation of pollen into soil and reduces the downward movement of pollen by water.

Dimbleby used his observations of the locking up of pollen in humic complexes and the downward movement of pollen by water to develop a qualitative model of soil pollen movement in a variety of soils[2] (Dimbleby 1962). Figure 2.1 below represents the theoretical distribution of pollen of different ages in soils where soil fauna are unimportant in reworking the soil and its soil pollen. Figure 2.2 presents the situation in biologically active soils where pollen of different ages has become mixed and the profile is homogenized. Based on these assumptions, Dimbleby, was able to inter-

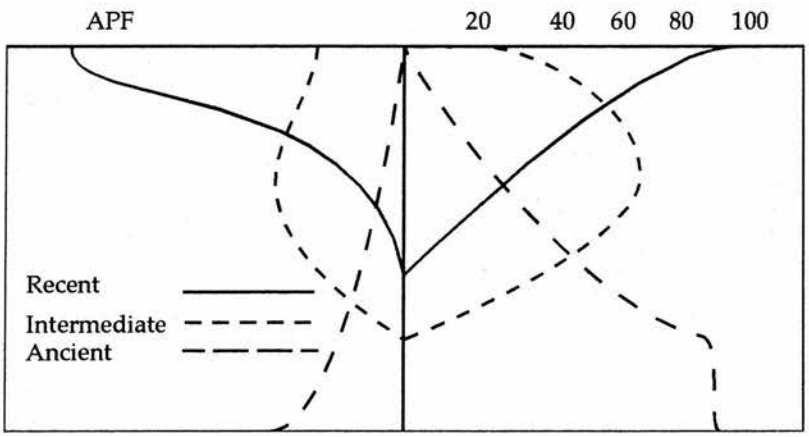


Fig. 2.1 Curves showing the theoretical distribution in soil of pollens of different ages (after Dimbleby 1985 p.7)

pret a great many soil pollen sequences some of which were of great depth, such as Pondhead enclosure (72 cm) (Dimbleby 1985).

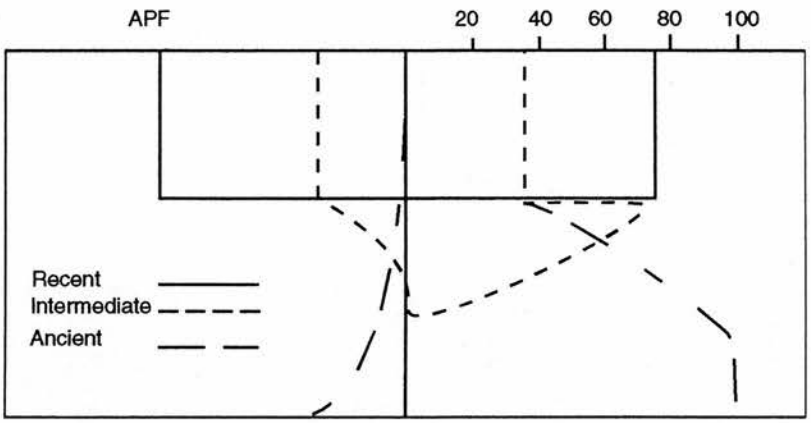


Fig. 2.2 Effects of homogenization on pollen curves of different ages (after Dimbleby 1985 p.17)

Dimbleby's model of soil pollen profile development has, however, been challenged by Andersen and Aaby in a series of papers (Aaby 1983 p.93, Andersen 1979 p. 71, Andersen 1984, *c.f.* Tipping *et al.* 1997). They propose that invertebrates are the dominant movers of pollen within soil profiles and that water perculation is a minor component in the movement of pollen (Unpublished research by Tipping *et al.* (1997) may also confirm this finding).

The use of deep soil profiles in palaeoenvironmental investigations was considered in a series of studies into pedogenesis and forest development in Draved forest (Denmark) (Aaby 1983, Andersen 1979, Andersen 1984). They used two approaches to examine the accuracy of soil pollen sequences. The first involved using hyphal frequency analysis as a proxy indicator of past soil invertebrate fauna in soil profiles (Andersen 1979, 1984). The second established a control sequence of vegetation change in the Draved forest through local stratified pollen sequences and historical data, to compare with the soil pollen sequences.

The research in the Draved forest demonstrated, that due to the activities of soil invertebrates, long pollen sequences from soils are not reliable indicators of vegetation change . Anderson and Aaby' s research indicated that the dominant mechanism for pollen incorporation into soil is by soil invertebrate activity. They found little evidence for pollen transportation by water or for humic complexes (Andersen 1979 p. 71, Aaby 1983 p.93).

The model ultimately put forward by Andersen (1984) (contra

Dimbleby 1962) for the preservation of stratified soil pollen sequences is dependent on three interlinked phenomena: 1) the type of soil, 2) the type of invertebrate population and the depth to which it operates, and 3) the residence time of pollen within the soil (pollen residence time is the amount of time pollen remains recognizable within a soil and is a function of species, soil pH and the level of biological activity). Of these three factors, the most important is soil type as this will determine the type of invertebrate population, depth of invertebrate activity and the residence time of pollen.

Buried neutral or alkaline soils, such as brown earths developed over chalk or clays, will seldom contain stratified pollen sequences. This is due to two factors: 1) high pH levels, and 2) active invertebrate populations capable of mixing pollen to great depths within the soil. These two factors produce short pollen residence times, but may also lead to the build up of highly resilient taxa such as *Pteridium* spores and degraded Lactucaceae. Paradoxically, because of the short pollen residence time, pollen recovered from such soils will be a good record of vegetation from immediately prior to burial, as most older pollen will have been destroyed.

More acid soils, such as acid brown earths, will also suffer from bioturbation, due to invertebrate activity, and in addition pollen will have longer residence times due to lower pH levels and lower levels of biological activity. Consequently, it is probable that such soils will contain homogenized pollen sequences. Older pollen assemblages in this soil type will be recycled upwards with more recent pollen moving downwards.

In very acid soils, such as podzols and gleys invertebrate activity is concentrated near the surface, and recent pollen is not incorporated into the soil by earthworm activity (Andersen 1984). The pollen spectra below the biologically active zone, is therefore, predominately a relict pollen assemblage derived from an earlier biologically active soil.

Over time acid brown earths may become progressively more acidic. With increasing acidity the level and depth of biological activity will decline and may even cease. This cessation of biological activity may result in the burial of a preserved pollen assemblage of an earlier vegetation community.

In most soils the degree of mixing is a function of time and level of invertebrate activity. If biological activity ceases soon after a vegetation

change as a result of burial or the onset of blanket peat formation, then a degree of pollen stratification may be recorded in the soil. The mixing of pollen in soils by invertebrates means that short pollen sequences (0-100 mm) from acid soils such as podzols are more likely to contain reliable information about vegetation change immediately prior to burial, than long sequences (Andersen 1979, 1988).

Archaeopalynological studies in the landscape

Ever since Iversen' s classic study of the Landnam phenomenon (1941), pollen analysis has been an important tool in describing human/vegetation relationships. The key area within palynology of human impact research has changed little since Iversen' s day, the dominant interest is still in deducing the nature of past human subsistence economic behaviour from its impact on the adjacent vegetation systems (Edwards and Whittington 1997). Research into human/vegetation interactions has revealed the long duration and significant effect of human activities on vegetation and the effect that these changes have had on the landscape of Scotland (Tipping 1994). This has led to the development of the concept of the cultural landscape in palynological and archaeological studies (Birks *et al.* 1988).

Interpretations of pollen data are complicated by the interaction of vegetational succession, climatic, soil and other factors with human activity (Edwards 1979). For these reasons, most pollen studies of human impact on vegetation are best done within multi-disciplinary projects where the significance of palynological data can be assessed by archaeologists and vice-versa. Studies such as the Ystaad project in Sweden demonstrate the potential richness of interpretation from such multi-disciplinary studies (Berglund 1988).

An important area of palynological studies of the cultural landscape is the study of past economic activity as it affected vegetation (Galliard *et al.* 1992). Two methods are predominately used to interpret past agricultural activity from pollen spectra; these are the indicator species approach (Behre 1981, Behre 1986) and the comparative approach (Gaillard *et al.* 1992). In this thesis the primary mode of interpretation of past agricultural practices is through the use of indicator species.

The indicator species approach relies on a limited number of taxa that have an ecological affinity for certain types of agricultural practice. The best indicators are obvious cultigens such as the cereals, but other useful

indicators include weed associates of cultivation and human settlement (*cf.* Fægri and Iversen 1991, Behre 1986). The major problem with indicator species is the limited number of pollen types with narrow, well defined, ecological tolerances (Birks and Birks 1980). Most indicators have overlapping distributions across a number of different ecological niches and plant communities. For this reason surety of interpretation relies on the presence of several such indicators, rather than just one or two (Behre 1981). A further difficulty is that many of these plants are entomophilous or autogamous and therefore poor pollen producers (Behre 1981). If the size of catchment is incorrectly matched to the size of the cultural landscape under study, insufficient numbers of indicators will be observed under normal counting procedures, either leading to prolonged counting or failure to recognize the type of anthropogenic episode in the sequence (Jacobsen and Bradshaw 1981, Berglund 1986, Edwards and McIntosh C.J. 1988).

The comparative approach is a relatively new development in European palynology (Gaillard *et al.* 1992). These complex studies involve the collection of surface sample data from a range of modern day vegetation types for vegetation and palynological analysis. The pollen assemblages derived from the known vegetation types are then statistically compared with fossil assemblages from lake sediments and peats to provide more detailed descriptions of past human activity. In southern Sweden the continued use of conservative farming techniques enables the use of the comparative method (Gaillard *et al.* 1992). To the authors knowledge however, the transferability of these studies outside of Sweden has yet to tested.

Fungal spores and other distinct incertae cedis fossils in Palynological investigations.

Fungi, broadly speaking, are a large and diverse kingdom with five main classes and over 100,000 described species (Table 2.1) (Ingold and Hudson 1993). Fundamentally, most fungi consist of two main components: 1) a system of tubes (or hyphae) used for feeding, which make up the mycelium; 2) specialized reproductive structures which can range in size from the microscopic to large toadstools, such as the edible mushroom (Ingold and Hudson 1993). Ecologically, the fungi's chief characteristic is an inability to photosynthesize, so to obtain nutrients they must exist as saprophytes on dead organic matter or as parasites of living organisms (Ingold and Hudson 1993).

1) Zygomycotina
2) Ascomycotina
3) Basidiomycotina
4) Deuteromycotina
5) Mastigomycotina

Table 2.1 Five main classes of the Kingdom Fungi (after Ingold and Hudson 1993)

Reproduction and dispersal in the fungi

Unlike the higher plants which produce single pollen grains or spores, fungi can be highly heterogenous in their reproductive strategies. These can include both sexual and asexual reproduction. Some species can

Class	Sexual spore	Asexual spore
PHYCOMYCOTINA		
Order Zygomycotina	Zygospore	Sporangiospore
		Chlamydospore
Order Oomycotina	Oospore	Oospore
		Zoospore
Order Chytridiomycotina	Resting spore	Zoospore
ASCOMYCOTINA	Ascospore	Conidium
DEUTEROMYCOTINA		Conidium
MYXOMYCOTINA	Myxomycete spore	

Table 2.2 Summary of the main types of spore produced by the Fungi (after Clarke 1994)

produce up to five different types of spore, e.g the rusts, depending on the stage of their life cycle (Ingold and Hudson 1993) (Table 2.2). This makes classification of dispersed fungal spores particularly difficult (Clarke 1994).

In order to be detected in the fossil record, fungal spores need to be produced, dispersed and recovered. The site of production will depend on a particular species habitat preference. Some species of fungi are generalists, whilst others have very specific ecological requirements. The mechanisms of spore production in the fungi are complex and varies between classes and even single species may produce several different types of spore or other remain,s such as hyphopodia or conidia (Ingold 1971, Ingold and Hudson 1993, Ellis 1971). Many fungi can also reproduce via hyphal fragments (Ingold 1971).

Dispersal of fungi is by a variety of complex mechanisms (Ingold 1971) and fungal spores can contribute greatly to the airborne microfossil content (Ogden 1974). From an archaeological perspective it is important to know that many fungi also produce spores in the tissues of plants, in the litter layer of soils, and to a considerable depth within soils (Dix and Webster 1995). Production of spores and other fungal tissue within soils mostly occurs within the vicinity of roots, but may also occur away from roots where conditions permit (Dix and Webster 1995). Table 2.3 summarizes data for isolates from different soil horizons beneath a spruce forest (source Söderstrom 1975) and Table 2.4. the distribution of mycelium within soil from a deciduous wood (source Frankland 1975).

Tables 2.3 and 2.4 show that fungal production occurs in the litter layers of soils where it may then be incorporated into and mixed with fungal communities living in the soil. It further suggests that where root penetration of archaeological deposits has occurred some disturbance and contamination of the fungal spore and hyphal content of the archaeological deposit may take place. Fungal spores and hyphae within a sediment may therefore derive from the air, water, and *in-situ* production within a soil or peat either

Soil Horizon:	A00	A0(F/H)	A	B
Species (n)	16	20/21	18	18
Isolates (n)	424	411/360	358	32

Table 2.3 Summary of the vertical distribution of fungal organisms in a spruce forest (N.B. in studies of fungal spores in soils it is common to culture on agar or other substrate the spores in order to identify the species, the products of such cultures are called isolates) (data from Söderstrom 1975)

Soil Horizon.	Length of mycelium (m/gram^{-1}dry soil)
A00	4118
A0(H)	2530
A	393
B	96

Table 2.4 Distribution of mycelium in the soil horizons of a deciduous wood (data from Frankland 1975)

associated with roots or away from roots. The high level of *in-situ* production however would appear to dominate inputs from other sources, as suggested by Clarke (1994) and van Geel (1978).

A brief introduction to fungal spores in palaeoecology

The role of fungal spores in palynological preparations has recently been reviewed by Clarke (1994), and this discussion will be based on her synthesis. Fungal spores have largely been neglected by Quaternary palaeoecology. The reasons for the neglect of fungal spores and *incertae cedis* fossils are related to the theoretical paradigms and methodological concerns of palaeoecologists (Clarke 1994). The dominant research questions within palaeoecology are based around research into the higher plants; key areas include long term plant succession, climate change and human impact (Fægri and Iversen 1989). Within these research paradigms it is not perhaps immediately obvious what the contribution of fungal spores and other *incertae cedis* microfossils could be. A further problem with fungal spore and *incertae cedis* fossils is methodological and relates to the difficulties in identifying fungal spores to a useful taxonomic level such as species, genus or even family. The work of Clarke (1994) and van Geel (1978, 1986) suggests that fungal spores may provide detailed information relating to the local environment at the point of deposition, if they can be identified to species or genus. However, Ingold makes the point that when discussing the identification of airborne fungal spores it is possible to identify many of these if not to species, then at least to genus (1971 p.174). There is no reason why this should not also be true for fossil fungal material.

Initial studies of fungal spores in lake sediments were pioneered by Wolf in studies in East Africa (Wolf 1966a, 1966b, 1967, Wolf and Cavaliere 1966). This was the first study to attempt a connection between dispersed fossil fungal spores and living fungi, and it led to the identification of spores of *Tetraploa aristata* in the fossil record. However, the aim of these

studies which was to demonstrate a link between pollen and fungal spore associations was, broadly unsuccessful.

After Wolf the next major contribution was that of Elsik. Elsik worked predominately in geological studies. He was able to demonstrate the value of fungal spores as stratigraphic markers in rock sequences (1969, 1976b, Elsik and Jansonius 1974). He was also able to use his spore sequences along with other palynomorphs in palaeoenvironmental reconstructions (Elsik 1976a, 1986b). Elsik also proposed a morphological system of classification and carried out work on the distribution of fungal palynomorphs in modern sediments (Elsik 1976b, 1986a).

The use of fungal spores and other *incertae cedis* fossils in Quaternary palynology was pioneered by van Geel through his research into raised bogs and lake sediments from the Netherlands (see van Geel 1978 onwards). This type of analysis involves recording the many diverse fossils found in palynological assemblages. Van Geel catalogues as many distinct microfossils as possible and often collaborates with other specialists from fields such as macrofossil analysis and insect analysis to produce in depth studies of peat and lake sediments. This type of study allows for a significantly improved analysis of local environmental conditions at the point of deposition.

Van Geel's work has demonstrated that fungal spores and other *incertae cedis* fossils are good indicators of local mire environments, and that some spores correlate well with certain types of vegetation found in peats (van Geel 1978). Van Geel also demonstrated an association between pollen assemblages and fungal spore assemblages that had earlier been sought by Wolf (van Geel 1986).

Van Geel's methodology involves giving the *incertae cedis* microfossils identified a Type No. This Type No. did not imply any biological classification of the fossil, but was a simple means of identifying the microfossils encountered. There are two methods used in van Geel's work to relate microfossils to modern day organisms. The first involves the identification of enough fossil material to enable an identification e.g. the use of spore bodies and spores and the host plant in the attribution of Type 14 to *Meliola c.f. niessleana* (van Geel 1978). The second method involves the subsequent identification of microfossils by experts in Mycology, Phycology, insect studies, or by the study of published material e.g. the attribution of Type 10 microfossils

to either *Bactrodesmium* or *Trichocladium.* (van Geel 1978). These procedures have led to a somewhat cumbersome system of over a thousand type fossils, many of which are published in the *Review of Palaeobotany and Palaeoecology,* but equally many of which are relatively unavailable to scholars in unpublished undergraduate and doctoral dissertations (van Geel unpublished catalogue data). Without visiting the Hugo De Vries Institute to compare microfossils, it is difficult to confirm identifications from published materials.

The identification fungal spores either by literature search or by consultutation with mycologists has not proved very successful over the years as van Geel's researches have to date identified 45 fungal spore types to family, genus or species level (see Appendix 7). Van Geel has to the time of writing catalogued in excess of 300 different fungal spore types (data compiled from Van Geel, 1978, Van Geel 1982, van Geel 1986, Van Geel *et al.* 1981, Van Geel *et al.* 1988, Van Geel *et al.* 1983 (a) Van Geel *et al.* 1983 (b), Van Geel *et al.* 1994).

In a recent study of fungal spores and other *incertae cedis* fossils Clarke (Clarke in press, Clarke 1994) used a morphologically based recording system to examine the distribution of fungal spores in modern and archaeological samples. Her morphological approach to identification allowed a consistent set of rules to be used to identify fungal spores within one of twenty two separate classes. Again, these were subsequently identified, where possible to species, genus or family, through the use of published material and consultation with mycologists (Roy Watling). Clarke had more success than van Geel in identifying fungal spores with 87 types identified to at least family level out of over two hundred fungal spores catalogued (Clarke 1994). All of the fungal microfossils identified by van Geel and his collaborators and by Clarke to species, genus or family and their taxonomic affililiations are presented in Appendix 7. Clarke's method of classifying fungal spores is discussed further in Chapter 3 and is described in Appendix 2, as it was the method chosen to catalogue the microfossils identified in the study.

Clarke's research was also concerned with evaluating the usefulness of the comparative method as opposed to the indicator species method within dispersed fungal spore analysis. To this end she examined a number of modern day analogue environments. The wide range of variation in fungal spore assemblages from apparently similar situations suggested that the

comparative approach was inappropriate for the study of dispersed fungal spore assemblages. Further research on this problem is currently being conducted at the Hugo de Vries Institute, Amsterdam (van Geel *pers. comm.*). Clarke, despite problems of spore attribution to known taxa, identified sufficient known fungal types to demonstrate that the indicator species approach could be used in the analysis of modern and archaeological samples.

Fungal hyphal analysis in Quaternary palaeoecology

Fungal hyphae are the individual filaments that go to make up the fungal mycelium or vegetative part of a fungal organism (Hawksworth *et al.* 1995, Ingold and Hudson 1993). They have a range of functions and may be involved in nutrition and reproduction (Dix and Webster 1995). Hyphae may be very diverse in form and function and for this reason they are used in the taxonomic differentiation of basidiomycetes (Hawksworth *et al.* 1995). Outside of the basidiomycetes, most hyphae are of two varieties unpigmented hyaline hyphae or pigmented hyphae. In studies from soil deposits it was found that the unpigmented forms tended to be rapidly broken down and that the pigmented forms dominated. In all of the palynological analyses of fungal hyphae (known to the author) carried out to date no report of unpigmented hyphae has yet been made (Andersen 1979, 1984, Aaby 1983, Middeldorp 1982). Hyphae can be found in most sedimentary environments and are derived either from autochthonous development or from transportation. The analyses of hyphae in this study are largely concerned with autochthonous hyphae that have developed within peats and soils as part of the development of the sediment.

Fungal hyphal analysis in peat and lake sediments

Fungi present on bog surfaces are important decomposers of organic material. Their hyphae grow beneath the surface of the bog in areas that are not continually under water (Middeldorp 1982). Analysis of hyphae in peat may therefore provide information relating to both vegetation and wet/dry cycles within mires. Studies in modern bogs (Collins *et al.* 1978) indicate that higher levels of fungal hyphae are found under *Calluna* with low levels on bare peat. Initial work by Huikari (in Middeldorp 1982) consisted of counting the number of hyphal fragments with the aim of gaining an insight into the activity of plant decomposers in a bog at the time of its formation. This was followed by Middeldorp who quantified hyphal

remains from a raised bog and found a relationship between hyphal numbers and the type of vegetation and also between high values of fungal hyphae and high levels of decomposition (1982). Middeldorp, however stressed the complex nature of the relationship of hyphae to the level of peat decomposition, which involved factors such as composition of the original mire vegetation and mire wetness as just two important factors affecting the numbers of recorded hyphal fragments. Hyphae in lakes may, if quantified, indicate the presence of soil erosion and the presence of reworked organic material in the sediment (Cushing 1964).

Fungal hyphal analysis in soils

The use of fungal hyphae in soil pollen analysis derives from experimental, and palaeoecological studies by Andersen in Draved forest, Denmark. In two papers Andersen laid out the theoretical and methodological basis for studies of fossil hyphal fragments (Andersen 1979, Andersen 1984). Pigmented hyphae are resistant to decay (Gray and Williams in Andersen 1984), although it appears that they are mechanically broken down or comminuted by a variety of soil fauna, principally invertebrates (Andersen 1984). Most of the living hyphae in acid soils are located in the surface humus layer or the A_1 layer of a mineral soil (Nagel de-Bois and Jansen 1971). It follows therefore that hyphal fragments become incorporated into soil over time by soil micro and macrofauna, chiefly earthworms and arthropods. Of these it is the arthropods that are chiefly responsible for the comminution of hyphal fragments in the soil. The main organisms of hyphal comminution identified by Andersen were the macroarthropods; Diplopoda, Isopoda, Diptera and microathropods chiefly the Oribitids. The length of comminuted fungal hyphae associated with macro and microarthropods was found to form two distinct frequency distributions through the analysis of faecal pellets (Fig 2.3).

The distribution of macro and microarthropods within the soil was found by Andersen to vary according to depth and soil type. Macroarthropods chiefly inhabit the upper levels of the soil whilst Oribitids may, particularly in brown earths, exist to great depths. The relative proportions of macro and microarthropods within the soil is therefore a function of depth and soil type. If Andersen is correct, then the distribution of hyphal length frequency within a buried soil profile is a reflection of the soil fauna and can aid in the reconstruction of the initial soil type. In brown earths

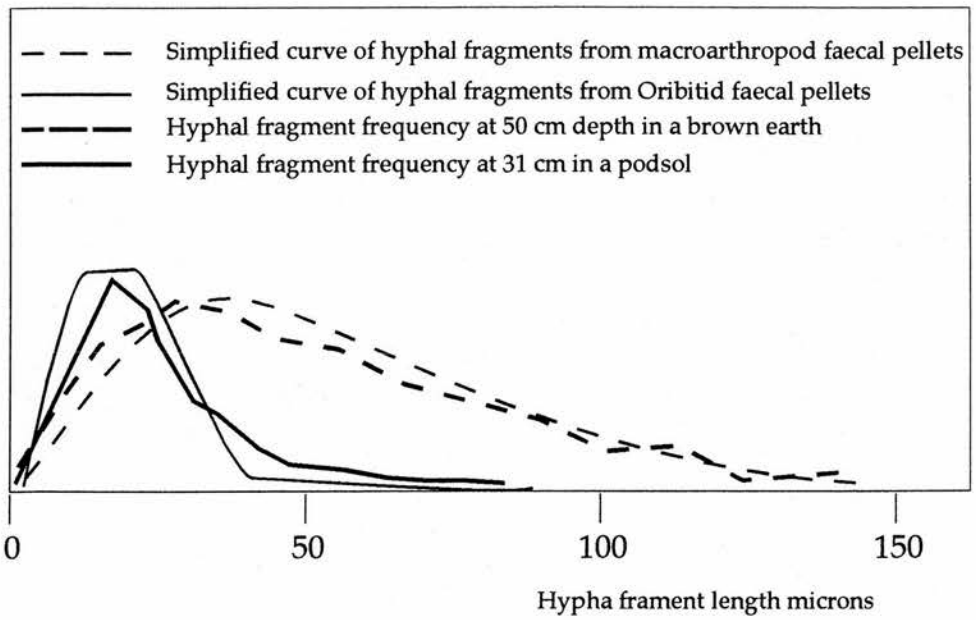


Fig 2.3 Hyphal fragment frequencies from macroathropods and *Oribitei* faecal pellets compared with hyphal fragments frequencies from a podzol and brown earth (from Andersen 1984 p. 301)

earthworms will transport lengths of hyphae up to 200 μm long deep within the soil. In podzols *Oribitei* are the chief means of hyphal comminution deep within the soil and this leads to the absence of long hyphal fragments at depth. In a biologically active soil such as a brown earth the distribution of hyphal fragments will be a smooth curve with a long tail of long fragments, whilst in a podzol the distribution curve will present a steeper aspect, and will predominately be of short hyphal fragments.

Algae in Palynofacies analysis

The algae are a large and diverse group formerly classified entirely in the plant kingdom, but several groups are now classified within the Protista. They exist in a variety of environments ranging from rock surfaces (e.g. *Gloeocapsa* which live on rock surfaces), to *Pediastrum* spp. which inhabit a variety of fresh water environments (van den Hoek *et al.* 1995). The principal divisions of the algae that are present in palynological samples derive from the Cyanophyta (Cyanobacteria), and Chlorophyta (Blue green algae) (van Geel 1986, Cronberg 1986). Both of these divisions are represented in peat and lake sediments where they form important ecological indicators (Round 1981, van der Hoek 1995, *cf.* Odgaard 1994).

Algal cysts and colonial algae may contain important information relating to water chemistry, for example the resting spores or akinetes of the Cyanobacteria are particularly helpful in identifying episodes of eutrophication in lakes (van der Hoek 1995, Round 1981, van Geel 1986, van Geel *et al.* 1994). Where it is not possible to identify an algal microfossil to species van Geel has catalogued them using his type number system. There are now a substantial number of algal types catalogued from Holocene fresh water and peat sediments (van Geel 1986).

Palynodebris analysis in Quaternary sediments

Assessment of the organic component of palynological preparations has seldom been attempted for Holocene pollen analysis (exceptions include papers by Hunt and Coles, 1988, Manum *et al.* 1985).

The notable exception to this is microcharcoal analysis. The analysis of microcharcoal in palynology has become a standard procedure, particularly in the investigation of fire regimes in semi-tropical environments (Clarke 1982) and in the interpretation of human interference especially in the Mesolithic of northwest Europe (Tolonen 1986). Microcharcoal in peat and lake sediments is often attributed to such activities as clearance (by fire) or as the result of domestic fires (Moore 1994).

For the other types of palynodebris encountered in palynological preparations it is necessary to consider the literature of palynodebris studies in pre-Quaternary geology. In marine sedimentary deposits the quantities and types of palynodebris present in sediments is primarily the result of distance from shore and other factors relating to sediment transport. The aim in recording palynodebris in pre-Quaternary palynology is to assess the oil potential of the sediment, and its relation to past coastlines.

Methods for classifying and quantifying palynodebris in geological settings are set out by Pocock (1981) (see also Chapter 3 below, Table 3.2)). The scheme of Pocock tends to dominate most of the recording schemes for palynodebris in marine sedimentary studies (Lorente 1986, Farr 1988).

Pocock (1981) divides palynodebris into three main categories; structured organic sedimentary matter such as identifiable plant cells, insect remains fungal hyphae etc, and unstructured sedimentary organic matter, which he categorizes as amorphous or semi-amorphous organic matter, the final group comprises both charcoal and if the carbonisation is not complet-

ed semi-charcoal. Within each of the above groups are further subdivisions. This classification scheme provides a relatively straightforward method for classifying the organic matter and palynodebris present in most pollen preparations. It has the advantage over other schemes used in pre-Quaternary palynology in that no ontological assumption is made about the origin of the material; in the study of Parry *et al.* (1981), discussed above the use of the term kerogen implies that the palynodebris component had undergone a set of diagenetic processes (heat, pressure and chemical activity) that had altered the form and structure of the organic materials. In most Quaternary sediments, although some diagenetic processes may have altered the palynodebris content (particularly chemical and biological breakdown), the effects of heat and pressure have not generally led to kerogen formation (Pocock 1981). An adaptation of the recording scheme of Pocock is used to record the palynodebris component of the samples examined in the case studies. Details of which are presented in Chapter 3.

Conclusion

The field of palynofacies analysis is by definition, broad, involving as it does a wide range of microfossils from several kingdoms of the natural world. For that reason this review has been highly selective in concentrating on those areas which contribute most to the study of archaeological sites and archaeopalynology (pollen and fungal spores). The development of palynofacies analysis in pre-Quaternary geology is based on the recognition that within a pollen preparation there was more information to be gained from the total assemblage than from the pollen alone (Combaz 1964, Batten 1973). With the exception of van Geel (1978) such an awareness has yet to develop in Quaternary and Holocene pollen studies. As van Geel has shown ,however, there is much more environmental information in a pollen preparation than has perhaps been thought. The challenge for palynofacies analysis is to demonstrate that it is worthwhile investigating the non-pollen microfossil component of pollen preparations in Quaternary sediments. This thesis is an attempt to develop the work of van Geel and the pre-Quaternary palynologists and to demonstrate that valuable palaeoenvironmental information resides in the "crud" that so often obscures even the best pollen preparations.

Chapter Three: Methodology

Introduction

This chapter presents the methodological issues relating to site selection, a summary of the aims of the case studies, and details of the sample selection, and sample collection procedures. Some information such as detailed descriptions of the sampling sites was deemed to be more relevant if discussed in the relevant case study chapters. The technique used in preparing the samples is described in Appendix 1, and the methods used in recording the palynofacies assemblage are described below. Diagrams were prepared using a variety of computer aided drawing techniques and relevant details of the various procedures employed are presented. Similarly details of statistical methods used in the analysis of the assemblages from two of the case study sites are discussed. The final section relates methods used in the preparation of samples for radiocarbon dating, tephrachronology and loss on ignition analysis.

Site selection

The aims of the thesis are explored and tested in three case studies. The study examined the use of palynofacies analysis in three areas of archaeopalynological research: 1) modern distribution data; 2) on-site palynology; and 3) cultural landscape studies (i.e basin peats or lakes). Initially, a project was sought that would have allowed each type of investigation in one geographical area, within the available time span of the Ph.D. Unfortunately, such a project could not be found. Instead separate projects investigating modern distributional data, on-site palynology and cultural landscape studies were conducted.

The criteria used to select the case studies for the thesis were as follows: 1) would the project contribute to the overall aims of the thesis as laid out in the introduction; 2) would the project be completed within the span of the Ph.D.? 3) would the excavation/survey provide an integrated framework for the interpretation of the results; 4) were the broad research aims of the (archaeological) project likely to be advanced by a palynofacies approach.

On the basis of these criteria, two archaeological projects were approached as collaborators, whilst a third (the study of modern distribu-

tional data) was designed 'in house' at the Department of Archaeology, University of Edinburgh. The collaborating projects were the Clava Cairns Project (on-site palynology), directed by Prof. R. Bradley, Department of Archaeology, University of Reading, and the South Nesting Palaeolandscape Project, directed by Dr. T. O'Connor, Department of Archaeology, University of Bradford (cultural landscape study).

Case Studies

Meldon Hills, Peebleshire

This study of modern palynofacies distributional data had two aims: 1) to test the hypothesis that microfossil assemblages represent discrete local micro environments; 2) to develop a set of criteria for identifying the presence of animal dung in the palaeoenvironmental record of archaeological sites. To this end, samples were collected from two transects centered on a heavily used upland sheep pen in the Meldon Hills south of Edinburgh (Chapter 4).

Balnuaran of Clava, Invernesshire

This study was of palynofacies distributions from buried soils and archaeological deposits, from the burial cairns at the cemetery of Balnuaran of Clava (Chapter 5). Here, a number of buried soil and archaeological sequences were obtained from beneath a series of burial monuments dated to the second and first millennia BC. The absence of any conventional pollen sources within the catchment of Balnuaran of Clava, due to agricultural improvement, meant that soil pollen analysis was the only means by which the palaeoenvironment at the site could be reconstructed. The close spacing of the monuments allowed the analysis of spatial variation of palynofacies assemblages both within and between a group of archaeologically linked monuments. The palynofacies approach was also used to discriminate between inter and intra monument variation within the cemetery. Finally, palynofacies analysis was used to reconstruct aspects of the palaeolandscape at Balnuaran of Clava.

Trowie Loch, Shetland

The final study was the palynofacies analysis of lake and mire sediments from Trowie Loch, Shetland (Chapter 6). The aims of this study

were to identify changes within mire palynofacies assemblages that could be related to the onset of agriculture, in particular to test the hypothesis that changes in the palynofacies assemblage occur as the result of the introduction of domestic animals such as cattle, sheep and pigs. Within the framework of the South Nesting Palaeolandscape project, the palynofacies study was to provide environmental data relating to the Neolithic and Bronze age landscape of the South Nesting area.

Sample selection

Meldon Hills, Peebleshire

In order to assess variation in the palynofacies assemblages between the sheep pen and the surrounding pasture two transects were layed out centered on the sheep pen. Samples were then collected at intervals along these transects (see Chapter 4).

Balnuaran of Clava, Invernesshire

At Balnuaran of Clava the aim was to sample short sequences of buried soils from beneath four large rubble built burial cairns. In this case sampling was done in close collaboration with the soil micromorphologists Prof. Donald Davidson, Dr. Ian Simpson and the excavator, Prof. Richard Bradley. By taking the soil micromorphology and soil pollen samples from adjacent locations the aim was to ensure that similar soil stratigraphies were being examined. Sample location information is given in Chapter 5.

Trowie Loch, Shetland

This study was principally to investigate landscape changes in a coastal area of Shetland associated with known Neolithic and Bronze age settlement. A sampling location with sufficient depth of deposit that was close to a number of undated excavated houses was sought. This was located through a series of trial corings using a Dutch corer in the Trowie Loch basin. A description of the trial coring is given below, in Chapter 6.

Sample collection

Meldon Hills, Peebleshire

Several methodologies for surface sample collections have been

employed in both pollen and fungal spore surface studies (Fægri and Iversen 1989, Clarke 1994). For this study the deposition of pollen, fungal spores and other materials was of greatest interest and so a technique such as the collection of moss cushions was considered. However, as moss cushions may have their own unique fungal spore flora and not therefore reflect the ambient palynofacies assemblage, a different method was sought. As Clarke (1994) had used small surface samples of soil in her study of the surface fungal spore assemblages, her methodology was adopted for this study for two reasons: 1) it allowed direct comparison with the results of her study; 2) it was a practical and quick method of sample collection.

At each location, approximately 3-4 cm^3 of surface soil was collected using a clean trowel into clean zip loc bags. Samples were then stored in the Departments refrigeration facility at 4 ° C until processing. Samples were stored at low temperatures to prevent a biological deterioration or fungal spore growth that might contaminate the samples.

Balnuaran of Clava, Invernesshire

Due to the shallow nature of the soils and difficulties such as soil stoniness, a pragmatic approach to sampling was required. Samples were obtained from cleaned trench baulks either by kubiena tin (25x50x100 mm), soil block or direct from the trench baulk in 1 cm thick slices into clean zip loc bags. A description of the sampling procedures used at each location is given in Chapter 5. Samples were stored as described in the Meldon Hills section above.

Trowie Loch, Shetland

To ensure that sufficient material was available for pollen analysis and radiocarbon dating, four overlapping cores were removed from the sampling location within an area of 1 m^2, to aid in inter core correlation. Two sediment sequences were recovered with a 5 cm diameter, 1m long Russian corer and two were obtained were obtained by use of a 10 cm diameter, 30 cm long Russian corer (Jowsey 1966). Lengths of core were described before being placed into clean lengths of plastic tube. These were then wrapped in plastic wrap and silver foil for transportation back to the Department. The cores were stored as described in the Meldon Hill section.

Sample preparation techniques

Most of the samples in this thesis were prepared using the density separation method in use at the Hugo de Vries laboratory, University of Amsterdam (Van Geel pers. comm.). This was done for two reasons: 1) there was the strong possibility of recovering phytoliths and other delicate microfossils from soil samples; 2) it was felt that this would make the final results more comparable with Van Geel's studies. Appendix 1 details sample preparation methodology. Because of the different nature of the sediments investigated, a variety of options to the basic technique were used and these are outlined in Table A1.1, Appendix 1.

Palynofacies analysis

Palynofacies analysis comprises the analysis of the recovered palynological preparation. However, in recording the microfossil component of a pollen preparation, the taxonomic level to which microfossils are catalogued depends on the overall nature of the research. As the dominant aim of this study is microenvironmental change and vegetation history, it follows that the most important part of the analysis is of the pollen and cryptogram spore content of the palynological assemblage.

Within the study a variety of taxonomic levels was employed depending on the type of microfossil. Pollen grains (both angiosperm and gymnosperm) cryptogram spores and fungal spores were all identified to the lowest taxonomic level possible. In the case of fungal spores and distinct *incertae cedis* fossils this often meant the assignation of a new form type for the particular form taxon (as outlined in Appendix 2). Algal communities, cysts and spores were generally identified to genus or family level. Descriptions of the various form taxa identified in the study are presented in Appendix 6, and photographs in Appendix 5. Most categories of palynodebris and animal remains were classified in broad categories based on those of Pocock (1981) discussed in Chapter 2. Palynodebris was generally recorded within large descriptive categories , Fig. 3.1. and Table 3.2 details the categories of microfossils identified in the analysis (see below also). However, in some cases distinctive types of palynodebris other than the broad categories outlined in Table 3.2 were identified and catalogued and the details of these additional types of palynodebris are given in the relevant chapter and in Appendix 6.

Category	Subcategory	example
Palynomorphs	Angiosperm pollen grains	Plantago lanceolata
	Gymnosperm pollen grains	Pinus pollen
	Pteridophyte spores	Filicales undiff.
	Fungal spores	Tetraploa aristata
	Algal cysts	Gleotrichia akinetes
	Colonial algae	Pediastrum
Palynodebris	Microcharcoal	carbonised woody material
		semi-carbonised woody material
Structured plant debris		Epidermis
		Seive plates,
		stomata
		Cuticle fragments
		phytoliths
		hairs
Other unstructured debris		Amorphous organic matter
		Gels
Animal fragments	Insect fragments	Chironomids

Table 3.2 Types of material identified during the palynofacies analysis

TLP=Pc x Mt/nm x V
Key
TLP=Total fossil pollen
Pc=Fossil pollen counted
Mt=Total number of markers
nm=markers counted
V= volume of sample.
Table 3.3. Formula for the calculation of pollen concentrations in a known volume of sediment

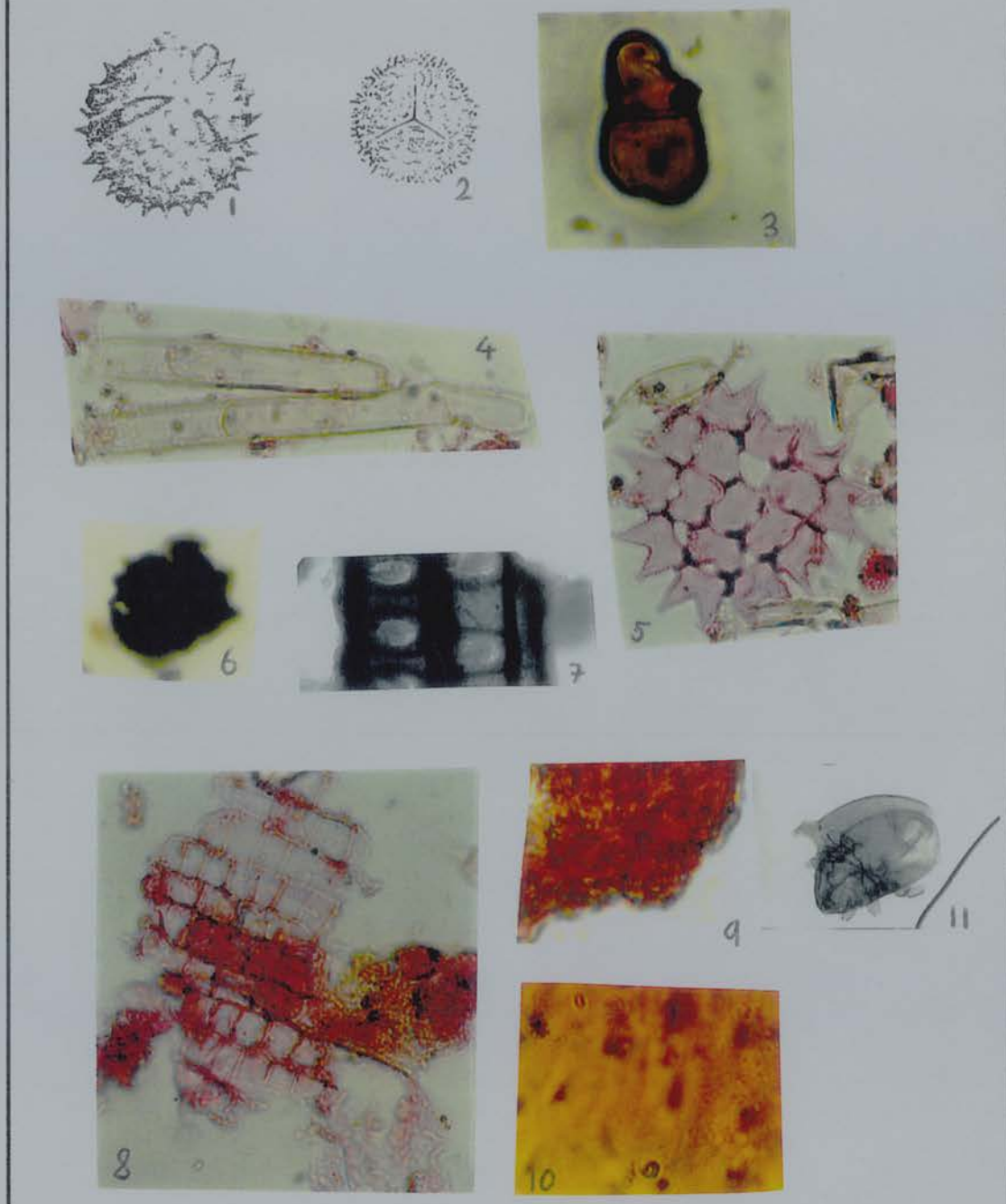


Fig. 3.1. Types of palynomorph and palynodebris classified within the palynofacies analysis; 1) Pollen grain, 2) Cryptogram spore, 3) Fungal spore, 4) Cyanophyta akinete, 5) Chlorophyta (Colonial algae), 6) Microcharcoal, 7) Semi-carbonised plant matter, 8) Structured plant matter, 9) Amorphous organic matter, 9) Humic gel, 10) Animal fragments

Pollen analysis

The choice of pollen sum depends on the type of the analysis and time available (Moore, Webb and Collinson 1991). In this study a basic sum of 300 pollen and cryptogrammic spore grains (TLP) was chosen (non-pollen microfossils and palynodebris were counted outside this sum-see below). For some calculations a pollen sum calculated without cryptogrammic spores (TP) was used, and details of this are outlined in Chapter 5. Three hundred pollen grains was chosen as the pollen sum for the following reasons; firstly and most importantly this sum is a statistically valid sample of the pollen present in a sample (Moore, Webb and Collinson 1991, Fægri and Iversen 1975); secondly, this sum allowed the collection of data from a greater range of samples within the time limits of the research. In some samples, particularly the buried soils at Clava, it was not possible to achieve this figure due to low pollen concentrations, in which case a lower sum of 200 was used and is indicated in the relevant text. At Trowie Loch, as the main interest of the research was in the regional and mire pollen component, locally produced aquatic pollen was excluded from the sum.

Concentration data for the samples from Clava cairns and Trowie Loch was calculated by the addition of known number of *Lycopodium* spores, to a known volume of sediment as outlined in Appendix 1. *Lycopodium* spores were added in the form of tablets obtained from the Laboratory of Quaternary Biology at the University of Lund, batch no. 124961 (Persson 1994). Calculation of pollen concentrations per unit volume of sediment was performed using the formula in Table 3.3 (after Fægri and Iversen 1989).

Processed samples were mounted on glass slides using Silicone oil as outlined in Appendix 1 and were examined using a Olympus BH1 microscope at x400 and x1000 magnification and phase contrast was employed when appropriate. Identifications were confirmed with the Department of archaeology's reference collection, published material including the Northwest European pollen flora, (Fægri and Iversen 1989, Moore, Webb, and Collinson 1991) and by the generous help of colleagues. Identification of cereal type pollen was on the basis of the criteria described by Andersen (1978), and included measurement of the a and b axis and *annuli* of uncrumpled grains. Pollen of *Corylus/ Myrica* is difficult to separate with a normal optical microscope and is referred to as *Corylus* type within the text (Bennet 1995). Plant nomenclature follows Stace (1995).

Pollen corrosion

There are several schemes for assessing pollen reliability now in use, e.g. Cushing (1967), Delcourt and Delcourt (1980), and Tipping *et al.* (1994). In this study, deterioration categories are based on a simplified version of those proposed by Delcourt and Delcourt (1980). Each pollen grain was assigned to one of six categories; well preserved, crumpled, corroded, degraded, split and concealed. The term degraded was used to describe exine thinning and ghosting (after Delcourt and Delcourt 1980), rather than the fusing of elements described by Cushing (1967). Deterioration categories for each count were assigned on the basis of the most dominant category present (Tipping, *et al.* 1994). Further assessment of the reliability of the pollen sequences from Clava Cairns was attempted through the use of comparisons of preservation within the major taxa, the use of ratios of spore concentration to pollen, and calculation of the number of taxa of spore and pollen present per sample. A discussion of the usefulness of such measures is given in Chapter 5 below.

Fungal spore and incertae cedis fossil analysis

Cataloguing, identification and recording of fungal, algal and *incertae cedis* microfossils

The non-pollen components of the palynofacies assemblage were recorded using a variety of different methods. Discrete palynomorphs, such as algal colonies, akinetes, fungal spores or *incertae cedis* microfossils, were recorded where possible to species or genus. If this was not possible then they were catalogued using the descriptive system of Clarke (1994) (Appendix 2). It is important to note that the numbers used in this study for a discrete microfossil type are unique to this study. Where a microfossil was subsequently confirmed as a previously identified type of either van Geel's or Clarke's this is noted both in the relevant text and in Appendix 6. All newly catalogued microfossils were described, photographed and drawn (photograph of the various microfossils encountered during the study are presented in Appendix 5, Figs 1-11). Identifications were made with the help of published material, with the assistance of Clarke at Edinburgh and that of van Geel, during a study visit to the Hugo de Vries Botancial Institute of the Free University of Amsterdam.

Discrete microfossil counting procedures

The procedure for counting discrete non-pollen microfossils was that used by van Geel and Clark (1978, 1994), rather than using a constant NPF sum, these microfossils are counted in addition to the pollen and cryptogram sum, during the normal pollen and cryptogram spore counting. This means that the fungal spore sum is not constant and makes the depth of fungal spore analysis dependent on the pollen sum, but as this is a study of the total assemblage rather than of the fungal spore and *incertae cedis* assemblage, the loss of information is compensated for by the use of a constant basis for calculation of the pollen sum. Percentage values of all discrete non-pollen microfossils (fungal spores, algal microfossils, *incertae cedis* microfossils) or NPF were calculated on the basis of the pollen sum $\sum NPF = \sum TLP +$ NPF (van Geel 1978, Birks and Birks 1980). The total concentration of fungal spores in each sample was calculated using the concentration formula given above for pollen grains.

Algae and algal communities

Where known, all algal and Cyanophyta remains have been attributed to their species, genus etc. as appropriate. Identification of algal material took place by reference to published material (West and Fritsch 1927, van Geel 1978, 1982, 1986, van Geel, *et al.* 1981, 1983 (a), 1994), by consultation with Dr. B. an Geel and by comparison with type material at the Hugo de Vries laboratory, University of Amsterdam. Descriptions of algal and Cyanophyta microfossils are also presented in Appendix 6 and photographs in Appendix 5.

Hyphal analysis

Analysis of the hyphal content of the buried soils from Balnuaran of Clava and the peat and lake sediments from Trowie Loch was carried out. For all samples the number of hyphal fragments within the pollen sum was recorded. In the buried soils the method of hyphal analysis devised by Andersen (1978) was used for a subset of samples. The total length of hyphae in a given sample as proposed by Middeldorp was calculated for peat and lake sediments from Trowie Loch (1982). Hyphal fragment length was measured by use of the eyepiece graticule during routine scanning.

Palynodebris

In this study the majority of the palynodebris identified consisted of charcoal, carbonized but not completely charred plant debris, plant cell debris, and other remains such as invertebrate animal fragments (Fig. 3.1). To a lesser degree, other debris, principally invertebrate remains and hair like structures, were also identified. Plant debris were not categorized on the basis of recognizable tissue for two main reasons; firstly there was insufficient recognizable tissue in a set of samples for a significant result from such an analysis, and secondly small fragments of plant tissue are generally insufficient to provide identification to species or genus (van Geel 1978). In addition to Fig. 3.1 descriptions of palynodebris during the study are presented in Appendix 6 and photographs in Appendix 5.

Palynodebris derived from plant material

Charcoal: Recognizable as opaque black fragments of material, usually angular in appearance and with occasional conchoidal fractures.

Brown carbonized plant material: Recognizable as fragments of dark brown woody material that has apparently been burnt but not totally carbonized. Within this debris plant structures such as cell walls and pores are still identifiable.

Structured plant debris: Comes in a range of colours, including yellow, green and brown and consists primarily of recognizable fragments of plant material, including cuticle, epidermis, plant transport material and hair like structures.

Other categories of Palynodebris

Three further types of palynodebris were recognized in the present studies; two of these are the result of chemical decay of plant and other materials, the third is a result of the mechanical decay of invertebrate remains.

Amorphous organic matter: Recognizable as mid-dark brown shapeless fragments of plant debris within which it is not possible to identify any structures. This may be for two reasons: 1) the fragments are too thick to allow the recognition of identifiable tissue fragments; or 2) the fragments are so decayed that the cell walls have disintegrated.

Humic "gels": Appear under transmitted light as dark golden brown to dark brown translucent angular fragments, with no cellular structure and occasionally with a conchoidal fracture.

Animal fragments: Because of difficulties in identification, all invertebrate fragments were considered as a single class. They are recognizable as transparent fragments which often take the shape of invertebrate parts, legs, carapaces etc.

Several alternative methods are used for the recording of palynodebris in palynological preparations (Traverse 1988). In pre-Quaternary palynology, palynodebris is recorded by estimating the area of palynodebris on a slide, by eye, from a set number of traverses (Pocock 1982). Another method would be to count the individual fragments of debris within the pollen sum (Traverse 1988). Neither of these two methods was employed. The first was rejected as being to crude an estimation, the second as it would be far too time consuming.

In this study, the use of the point count estimation method as developed by Clark (1982) for charcoal analysis was used to estimate the palynodebris component of the palynological preparation. The addition of *Lycopodium* spore tablets allowed the calculation of the area of palynodebris in a unit volume of sediment, using equations published by Clark (1982) (Appendix 3). Clark's method is based on the use of sampling theory to estimate the area of charcoal or other approximately two dimensional material on a plane surface. The point count method was found to be a practical, quick method of classifying the palynodebris content of a palynological preparation. In some samples occasional rare fragments of palynodebris were very abundant, principally hair like structures. Where structures such as hairs, were present they were recorded by counting individual examples.

The use of palynofacies data in identifying wet/dry mire phases

By combining the results of fungal hyphal analysis with palynodebris analysis and non pollen microfossil analysis, it is possible to identify periods of wetter and drier conditions within a mire. This interpretation of wet and dry phases is principally based on research by Middeldorp (1982) and van Geel (1978, *et al.* 1988).

The presence of algal taxa within basin mires can be interpreted as

a result of wetter conditions, either due to seasonal flooding, or autogenic changes within the mire or both acting together (*cf.* Godwin 1981). In wetter conditions the ecological preferences of algal taxa may be used to develop hypotheses as to the nutrient status of water on the surface of the mire. *Pediastrum, Botryococcus,* and *Tetrahedron minimum* tend to be prefer oligo-mesotrophic or shallow water conditions, whilst *Gloeotrichia, Spirogyra,* Zygnamataceae and Desmidaceae tend to colonize meso-eutrophic water (Round 1981, van Geel 1986, van Geel *et al.* 1989, van Geel *et al.* 1994).

A further indicator of wet/dry periods within peats can be derived from hyphal length frequency data (Middeldorp 1982). Middeldorp found that within the blanket peat he studied, dry phases dominated by *Eriophorum vaginatum* and *Calluna vulgaris* contained average lengths of hyphal fragments c. 135 m cm^{-3} whilst wet periods characterized by *Scheuchzeria palustris* had lower levels of hyphal production, c. 25 m cm^{-3}: Very dry periods with slow peat growth and occasional areas of bare peat also had low levels of fungal hyphae, c. 4-14 m cm^{-3} (Middeldorp 1982).

Preparation of pollen and palynofacies diagrams

Calculations of pollen and palynofacies sums, concentration data and palynodebris data, was done within an EXCEL spreadsheet. The processed data from EXCEL was imported into a specialist graphing program (Deltagraph v. 3.) where pollen and palynofacies diagrams were produced. These diagrams were then completed inside Adobe Illustrator v. 5.5. In all the pollen diagrams, only major taxa are presented graphically. Minor taxa, usually less than 2% of the pollen sum, are presented as counts in tabular form (as described by Bennett *et al.* 1993). The pollen and palynofacies diagrams are divided into a number of local pollen and palynofacies zones as described below.

The data from Trowie Loch and Balnuaran of Clava were treated slightly differently for reasons that are explained below.

The pollen and NPF assemblage from samples analysed at Balnuaran of Clava are considered to reflect the sampling environment. Pollen from buried soils is primarily derived from local vegetation (Aaby 1983, Andersen 1988, Groenman-van Waateringe 1986, Tipping *et al.* 1997). For this reason the palynofacies assemblage is used to produce Local Palynofacies Assemblage Zones (LPfAZ) for all the sampling locations exam-

ined at Balnuaran of Clava.

At Trowie Loch there is clearly a distinction between a regional pollen component that dominates the lake sediments, and which makes a significant albeit unquantifiable contribution to the peat deposits, and locally derived microfossils and palynodebris such as fungal spores etc. Following the convention of van Geel (1978) and because it is not possible to state with certainty the origin of pollen in the sediments at Trowie Loch. Local Pollen Assemblage Zones (LPAZ) are used to describe the (TLP) pollen component of the palynofacies assemblage while Local Palynofacies Assemblage Zones (LPfAZ) are used to describe the non-pollen spectra.

Multivariate statistics in the analysis of pollen and palynofacies assemblages

Multivariate statistical techniques have been used in the studies at Meldon Hills and Balnuaran of Clava to examine the group structure of the fungal spore data, in particular the degree of spatial variation within the datasets.

There are many multivariate techniques available to palynologists. The most common methods employed are either clustering methods or geometrical methods (Birks and Gordon 1985). Clustering methods aim to produce groups based either on similarity or dissimilarity techniques, whilst geometrical analyses are based on reducing the overall data set to a number of important variables that may then be projected graphically. Both of these techniques are complementary and it is common practice to use both types of analysis in investigating group structure. In this study the structure of the data sets has been explored through the use of Ward's method cluster analysis and principal components analysis. All analyses were carried out using SYSTAT v. 5.1 on a Macintosh computer.

Ward's method of cluster analysis (Sum of squares clustering), is a "hierarchical agglomerative clustering procedure" (Baxter 1994 p.141), which means that at the beginning of the procedure each object (sample) is considered as one cluster, clusters are then successively formed from similar objects (samples) until all the objects (samples) are clustered. In Ward's method, clusters are selected to be joined that will produce the least increase in variability (Baxter 1994). The advantage of Ward's method of clustering is that it tends to produce clusters on the basis of group similarity, as opposed to

object similarity. Overall, this makes for more interpretable results. However, a drawback is that this method will tend to overlook outliers within the dataset.

Principal components analysis (PCA) is a commonly used geometrical method of analysing the structure of complex data sets. Simply put this technique aims to reduce the data to a series of component axes of variation, either pre-defined, or based on the number of variables used in the analysis. The first principal axis, or component is aligned on the maximum amount of variability within the data, subsidiary axes are aligned in the direction of progressively less variability. PCA aims to reduce complex data sets to a number of components that describe the main trends within the data. The contribution of individual taxa to the variability of the data set is derived from the component loadings. PCA is sensitive to scale variations so it is common practice to standardize data prior to analysis. This standardisation has the drawback of increasing the influence of minor components of the data set and for this reason it is common practice to leave minor taxa (generally less than five percent of the sum) out of the analysis (Birks and Gordon 1985 p.160).

Dating

Three dating methods were employed in the two archaeological projects. At Balnuaran of Clava, AMS radiocarbon dating of small fragments of charcoal was the principal dating method. This was coupled with archaeological dating based on stratigraphic and cultural associations of the excavated cairns. Throughout the text the abbreviation BP signifies uncalibrated dates before present (1950) and BC signifies calibrated radiocarbon dates using the calibration curve. Dates were calibrated using CALIB v.3.0 (Stuiver and Reimer 1993).

At Trowie Loch, the mire was in a basin part of which was composed of limestone. After discussion with Dr D. Harkness at the NERC dating laboratory at East Kilbride and Dr. R. Housley of Glasgow University, two strategies were adopted for dating the basin deposits at Trowie Loch: tephrachronology and radiocarbon dating. It seemed probable that the lake sediments may have been more affected by the "hard water effect" than the peat deposits. The organic component of the lake sediments was liable to obtain at least some of its carbon from old carbon dissolved in the water. The

peat sediments, on the other hand, are less affected by the hard water effect as they obtain much of their carbon from atmospheric sources (Housley pers. comm.). Because of this attempts were made to obtain dates through the presence of volcanic tephra particularly from the lake sediments. For peat sediments of the mire, conventional radiocarbon dates were obtained.

Preparation of samples for radiocarbon dating

Balnuaran of Clava

Samples for radiocarbon dating from this site were selected and submitted by the archaeologist (R. Bradley) from the same contexts as analysed for soil pollen and soil micromorphology. All the sites were dated by the AMS method,using where possible single fragments of young wood. Dating took place at the NERC dating facility in East Kilbride.

Trowie Loch

Radiocarbon dating

Three samples were submitted for radiocarbon dating from Trowie Loch. Samples were selected for radiocarbon dating on the basis of important changes in the pollen stratigraphy. Samples for radiocarbon dating were bulked from the two cores obtained using the 30 cm long Russian corer. The outer surface of the core was removed, to avoid any possible contamination. Details of which samples were submitted and the justification for their selection are in Chapter 6. Radiometric dating of both the humic and humin fraction took place in the laboratory of Beta Analytic, Florida, USA.

Tephrachronology

Samples were prepared following the method of Dugmore (1996). The methodology is outlined below in Appendix 4. Prepared samples were analysed on a polarising microscope at a number of magnifications, by both the author and Dr. A. Dugmore.

Loss on ignition analysis

To assess the variation in inwashed mineral material, loss on ignition analysis was carried out on the peat and lake deposits from Trowie Loch. Slices of peat approximately 1 cm^3 were extracted from the core at 4 cm

intervals, dried for several days at 40°C and then weighed prior to incineration at 550 °C for three hours. The resulting residue was again weighed allowing the calculation of the percentage loss of organic material.

Conclusion

Palynofacies assemblages in the study of Quaternary sediments requires a broad approach to palaeoenvironmental analysis. Palynofacies analysis is based on pollen analysis and many of the techniques used are derived from palynology e.g. sampling strategies, sample preparation. By integrating microfossil analysis from several different kingdoms e.g. algae, fungi, and the higher plants the analyst may be able to produce more detailed reconstructions of past environmental conditions.

Chapter Four: Meldon Hills, Peebleshire

Introduction

This chapter discusses the aims, objectives and results of the palynofacies study in the Meldon Hills, Peeblesshire. This study examined the variation in modern palynofacies distributions between a sheep pen and adjacent areas of poor grazing and improved pasture. A short section outlining this case study in the context of the thesis is followed by a description of the environs of the site, and the sampling locations. The final parts of the chapter then discuss the results and interpretations of the data.

Aims and objectives

The study used modern surface samples to test two hypotheses related to the overall aims of the thesis: 1) to examine whether pollen and non-pollen microfossil assemblages correlate with local and macroenvironmental change, 2) to investigate whether the presence of animal dung will produce a distinctive assemblage of fungal spores. The study was conceived of as an attempt to replicate Clarke's (1994) observations of fungal spore heterogeneity within closely spaced samples, as discussed in Chapter 2. Griffin (1972) and Christensen (1989), in reviews of modern fungal ecology have demonstrated that there are distinctive fungal communities associated with a variety of ecological situations. Dix and Webster (1995), however, point out that soil fungal communities are among the most diverse. It is this diversity of fungal spore communities which may lead to the heterogeneity in sub-fossil fungal spore distributions observed by Clarke (1994). The aim of this study was therefore to examine how responsive fungal spore assemblages are to environmental variation at short spatial scales i:e over short distances, and to compare the variability of the fungal spore assemblages with that of the pollen assemblage.

The study therefore used a relatively simple example of a human impact, an upland sheep pen and its environs, as its focus. By collecting small samples of soil along transects, away from the sheep pen, the objective was to observe variations in the pollen and non-pollen microfossil record that could be related to changes in vegetation, grazing

pressure and dung frequency.

Location

The study area lies in the Meldon Hills, part of an extensive series of uplands in and around Peebles. The study area itself was centered on a small sheep pen located to the south of White Meldon at an elevation of 275 m at NT 215 419 (Fig 4.1) See also photographs Appendix 5, Figs. 12./12.1). This sheep pen was chosen for it's situation in an area of upland grazing, which was close by an area of improved pasture. When first visited (Feb 1994) it was still in use as a temporary store for animal feed and the large quantities of fresh sheep droppings indicated it was frequently used by sheep for shelter. However, on the most recent visit (July 1997) the condition of the pen had deteriorated considerably and appeared to be abandoned and neglected, possibly reflecting seasonal use.

Site environs

The solid and drift geology in the study area consists of Ordovician sandstones and siltstones of the Shinnel formation (Fig. 4.2 A), with a drift cover of boulder clay and thin soils developed over bedrock (Fig 4.2 B). Soils in the study area are brown forest soils of the Ettrick series (Fig. 4.2 C).

As the site is an area of upland grazing, the vegetation reflects both the altitude and land use. The vegetation in the vicinity of the sheep pen is a mosaic of poor unimproved grassland with heather and bracken occasionally dominant, juxtaposed by an enclosed area of improved pasture, immediately to the north. Within the sheep pen and its immediate environs, the grazing is noticeably better than that of the surrounding moorland, and is comparable to the improved grazing. The land is classified by the Macaulay Land Use Institute as class 3 "capable of satisfactory stocking rates" (1982), and the landuse in the vicinity of the pen is upland pasture for sheep.

Sampling Locations

The following variables were assessed at each sampling location (Fig 4.1): grazing pressure was estimated as light, medium or heavy based on

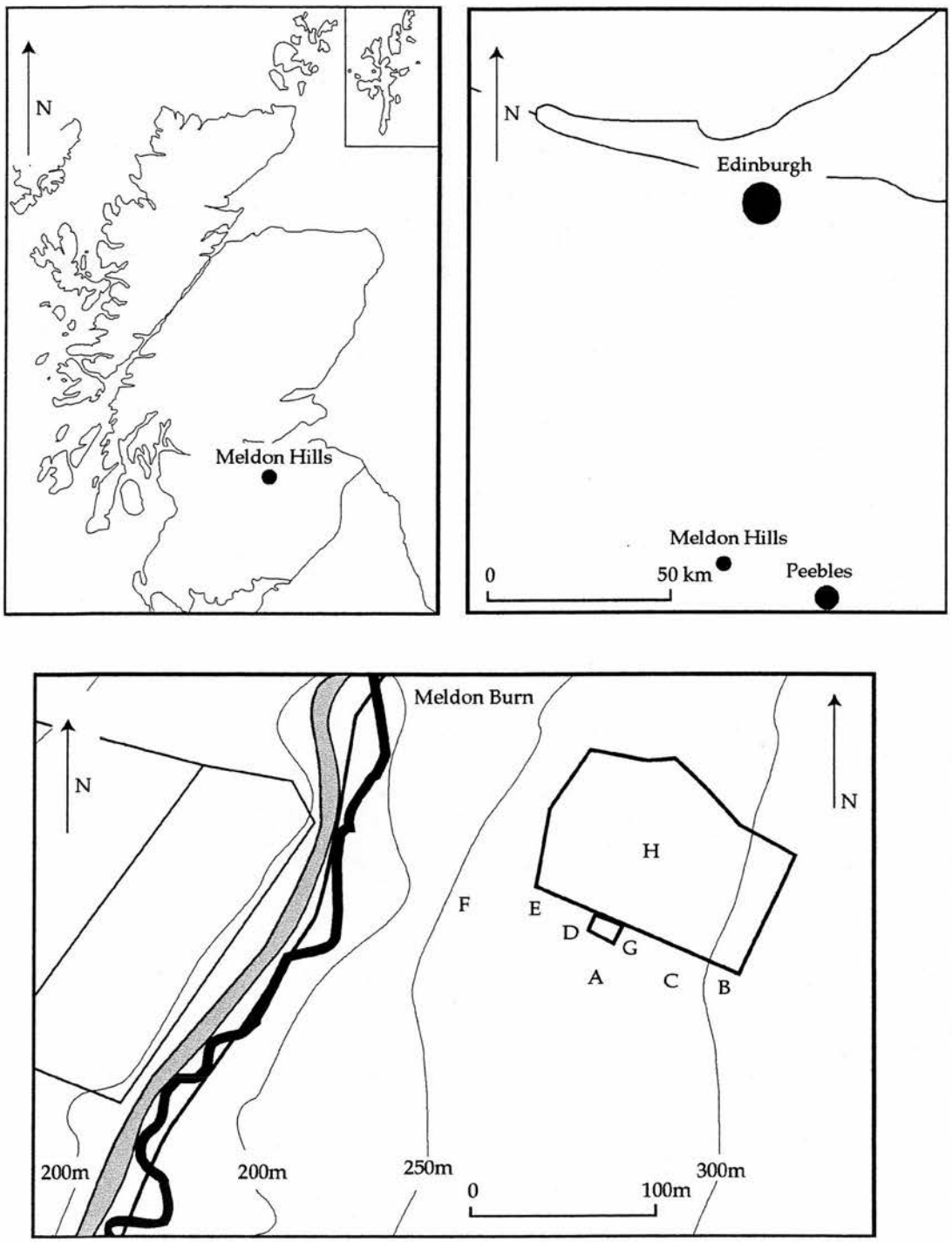


Fig. 4.1 Location map of study area, Meldon Hills, near Peebles.

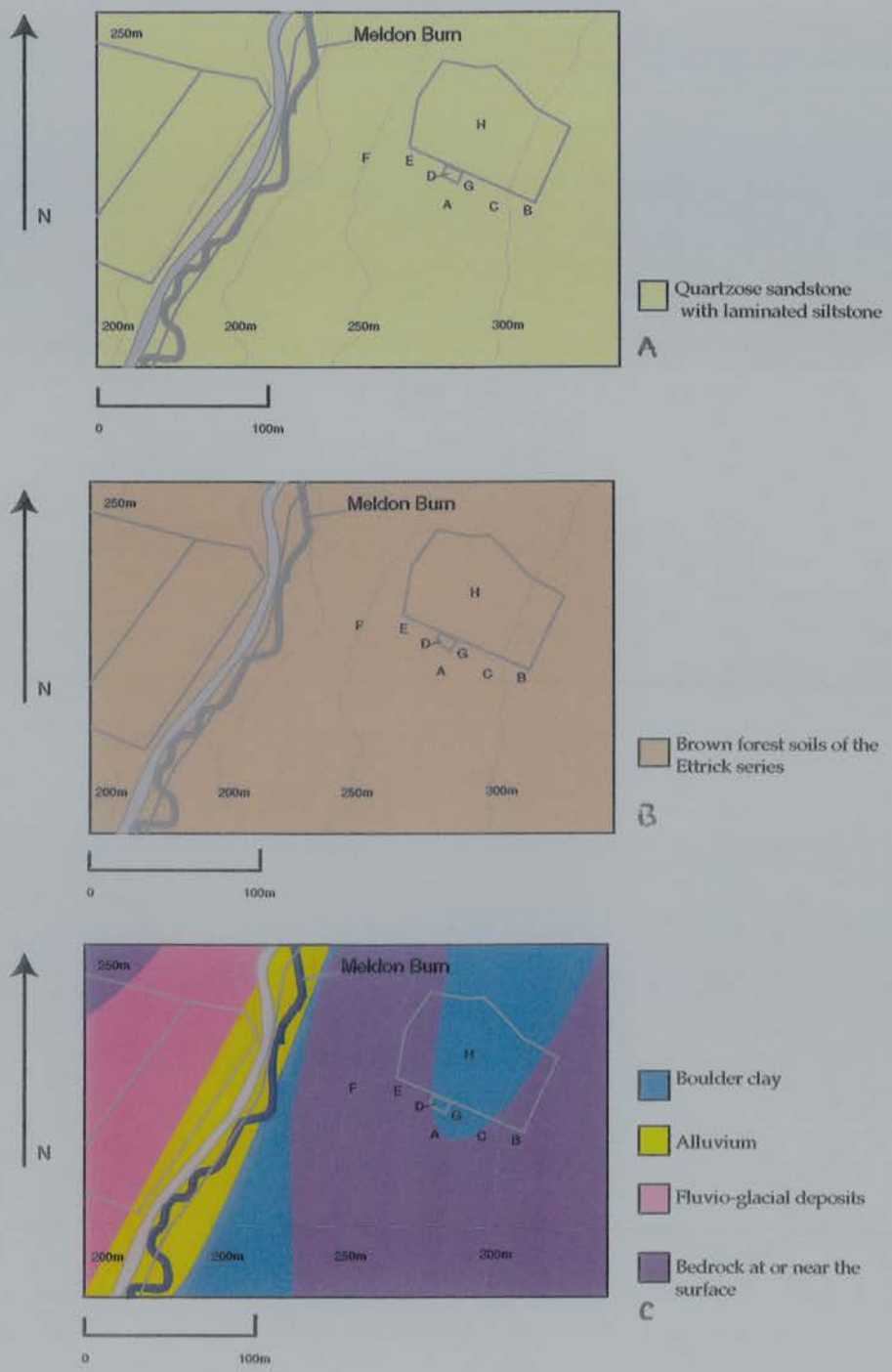


Fig. 4.2 Solid geology (A) (after British Geological Survey 1996), soils (B) (after Macaulay 1975) and drift (C) (after British Geological Survey 1996) at Meldon Burn, sheep pen.

sward length and type of vegetation present, dung frequency as light, medium or heavy based on the number of sheep droppings/ m^2 around the sampling location, and the vegetation was classified as unimproved pasture (M)

Sample	Grazing pressure	Dung frequency	Vegetation type
A	medium	low	M
B	medium	low	M
C	medium	low	M
D	high	high	S
E	medium	low	M
F	low	low	M
G	high	high	S
H	high	medium	I

Table 4.1 Environmental variables recorded at each sampling location.

improved pasture (I) and pasture within the sheep pen (S) (Table 4.1.).

Results

Samples from grazed impoverished moorland (A, B, C, E, F)

Pollen, spore and non-pollen microfossils were well preserved. The samples from grazed unimproved pasture are characterized by high frequencies of *Calluna vulgaris* and Poaceae pollen: other important taxa are *Plantago lanceolata*, Asteraceae lactucoideae type, and Cyperaceae (Fig 4.3 and Table 4.2). Fungal spores form approximately 30% of the palynomorph assemblage, and are dominated by Phomoids type and ASI010 (Fig. A5.1.2), with types ASM006, ASM007 and ASM020(Figs. A5.3.5, 3.6, 3.11) also important. The frequency and occurrence of fungal spore taxa show greater variability than do the pollen taxa (Fig 4.3, table 4.4). Palynodebris is predominately derived from structured plant material and amorphous organic matter. Higher levels of palynodebris were observed in samples A and B than in samples C, E and F (Table 4.4).

Samples from improved pasture and sheep pen (D, G,H)

These samples all had reduced frequencies of *Calluna vulgaris*

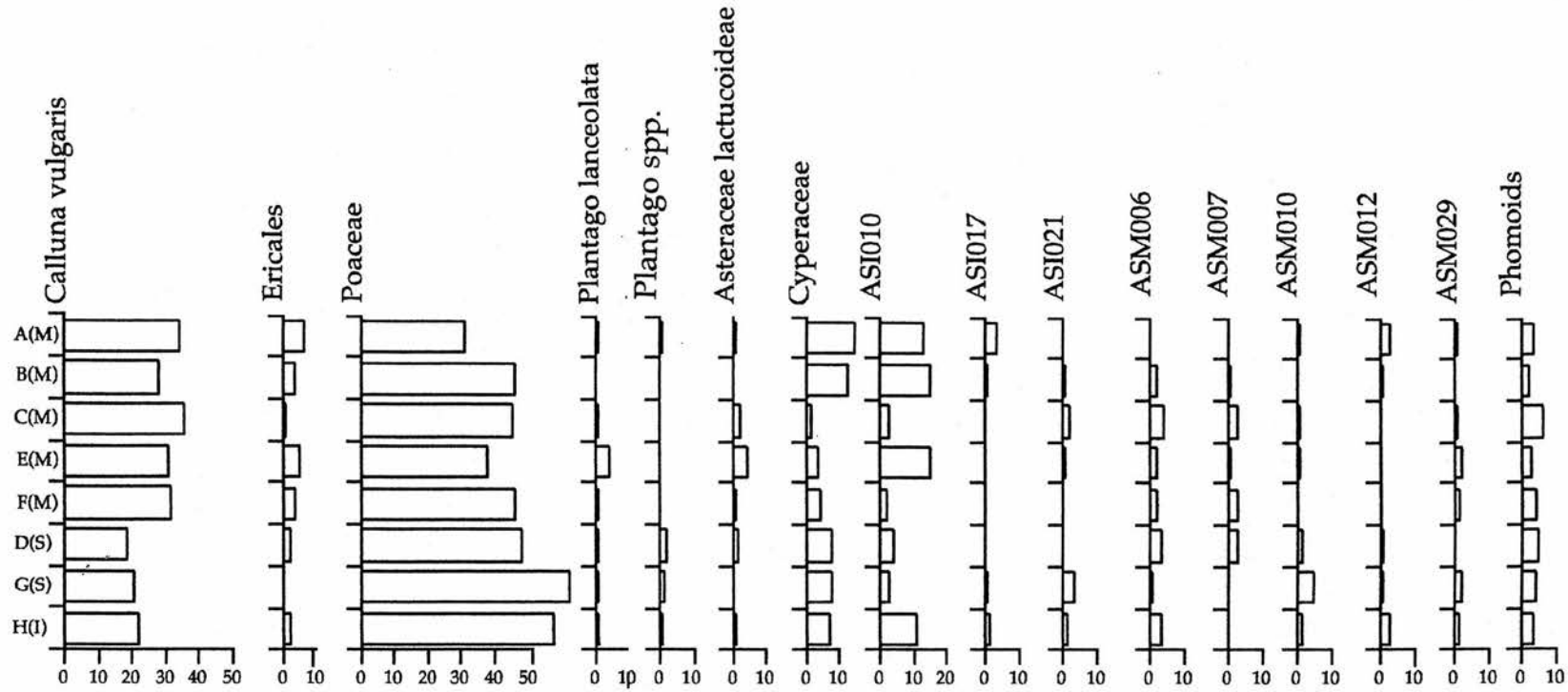


Fig. 4.3 Selected pollen taxa and non-pollen microfossil percentage diagram at Meldon Hills.

Pollen	A(M)	B(M)	C(M)	E(M)	F(M)	D(S)	G(S)	H(I)
Alnus	1		1	1		2	1	1
Betula	1	2	1		4	3		
Coryloid	5				3			
Pinus	7	9	1	8		3	2	3
Quercus	2	3	1		2	8	1	3
Tilia	1	1						
Artemisia					2			
Alchemilla type		1	2			6		
Cereal type						1		
Chenopodiaceae			1	1		1		
Caryophyllaceae			2		3	3	1	3
Cornaceae				1				
Rubiaceae			2	2		2	1	2
Potentilla type			1	2	3			
Brassicaceae						1		
Lotus	1							
Ranunculus type	3	1		2		6	4	2
Rosaceae	2				2		1	2
Rumex acetosa type							1	1
Succissa pratensis						1		
Scabiosa columbaria	1							
Ulex						1		
Apiaceae						1		
Sphagnum	8		1	2	2	5		4

Table 4.2 Minor pollen taxa at Meldon Hills (n)

SPORES	A(M)	B(M)	C(M)	E(M)	F(M)	D(S)	G(S)	H(I)
ASI025			1	1		1	2	1
ASI026			1	7	3			1
ASI027		2	1	1	2		6	1
ASM003			4	4		7	5	4
ASM004		1	2					1
ASM018		1	1	1				1
ASM020		3	5	2	9	8	2	4
ASD002	1		1	3	1	2	2	3
MOI004	6			1			1	
MOI007			1		3	1		
DII002					1			1
DII003			3			1		
DII004		2			2		1	
TRI005	3							1
TRI006			1		1			
MUI004				2				
MUI008			5			1		
TORULOID FRAGMENT	6	2	1			3	2	2

Table 4.3 Minor non-pollen microfossil form taxa at Meldon Hills (n)

	A(M)	B(M)	C(M)	E(M)	F(M)	D(S)	G(S)	H(I)
Plant cells	22.59	17.35	8.87	3.63	9.27	6.05	2.41	2.82
Amorphous organic matter	48	37.51	4.44	8.47	8.47	5.65	2.82	5.64
Insect fragment	1.21	1.61		0.81	1.61	0.4	0.4	1.21
Hyphae	7.66	4.03		2.42	2.42	2.02		6.05

Table 4.4 Palynodebris area data at Meldon Hills (mm^2/cm^3)

pollen and a corresponding increase in Poaceae pollen and *Plantago* spp. compared with the samples from the adjacent unimproved pasture. The sample from the centre of the sheep pen also had a number of cereal pollen grains, and other weeds such as Brassicaceae and Caryophyllaceae. The fungal spore assemblage formed c. 30% of the overall palynomorph assemblage, and was broadly similar to that from the unimproved pasture. Levels of the Sordariacious types ASM003 *(Tripterospora* type) and ASM010 *(Podospora* type) (Figs. A5.3.2, 3.7)are higher in sample D(S) and G (S). Palynodebris levels are similar to those from samples C, E and F.

Discussion

The following discussion will chiefly concentrate on the analysis of the fungal and pollen data with some discussion of the palynodebris data. The results of each type of information are each considered independently before the total assemblage is discussed.

Pollen analysis

The samples from semi-natural unimproved grazing are characterized by *Calluna vulgaris* frequencies in excess of 30% and higher frequencies of Ericales pollen than those from the improved pasture and the area of the pen. There is some variation within the other taxa present: in particular the proportions of Cyperaceae, Asteraceae lactucoideae, *Plantago lanceolata* pollen, and *Sphagnum* spores fluctuate, reflecting small scale vegetation differences between the sampling locations. Of particular note is the higher level of Cyperaceae and *Sphagnum* at location A (M) indicating wetter conditions.

The samples from the improved pasture and sheep pen all have a higher frequency of Poaceae and Cyperaceae pollen, which serves to differentiate them from the unimproved pasture. The sample from the sheep pen interior (D) in addition contains several minor herb taxa that may derive from hay, straw and feed brought into the pen e.g. a single grain of cereal type, Brassicaceae pollen and Caryophyllaceae pollen, or transported from feeding areas and deposited as dung (King 1977, Moe 1983, Akeret *et al.* 1999).

To summarize, it is possible to distinguish the samples from the sheep pen and improved pasture from the unimproved pasture on the basis of their respective pollen spectra.

Non-pollen microfossils

Non-pollen microfossils were counted within the pollen sum, and there is a relatively constant proportion in these samples of approximately 3

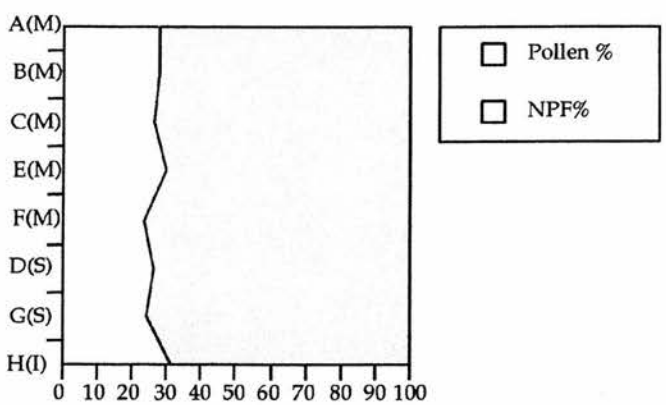


Fig. 4.4 Pollen: Non pollen microfossil ratio in the samples from Meldon Hills (as percentages)

pollen grains to 1 non-pollen microfossil (NPF, mostly fungal spores) (Fig. 4.4). The reasons for this regularity are not known but it will be interesting to see if further studies of modern spectra reveal a similar ratio. The existence of a similarly constant ratio was not observed in the analysis of fossil data during the study of archaeological materials (Chapters 5, 6 below).

Of 33 form taxa identified during the analysis, 6 were wholly new form types and so are not included in the following remarks as they occurred only as single microfossils in a single sample. Of the remaining 28, 8 are

identifiable to at least family or genus level (Table 4.5, *cf.* Appendices 5, 6 and 7). In Table 4.5, the type numbers of the microfossils identified in this study according the cataloguing schemes of Clarke and van Geel are given, as well as the species, genus or family name. The bulk of the identifiable non-pollen microfossils are associated with dung and/or rotting vegetation. For example, ASI027 (Figs. A5.1.7), ASM003 (*Tripterospor*a type) and ASM010 (*Podospora* type) (Figs. A5.3.2, 3.7) are all members of the Sordariaceae (Lundqvist 1972). Another taxa associated with dung found during this

Type No.	Clarke type	Van Geel type	Type name
ASI027	ASI037		Sordariaceae
ASI029	ASI078		Inocybe type
ASI041	ASI020		Endogonaceae
ASM003	ASI054,ASI070	T.169	Sordariaceae c.f. Tripterospora
ASM004	ASD001	T.55	c.f. Chaetomium/Lophitricus type
ASM010		T.112, T.369	Sordariaceaec.f. podospora
ASM029			Sporormiella type
MUI004			Dichtyosporium type

Table 4.5 Fungal spore taxa and their comparatives in samples from Meldon Hills

analysis was ASM029 *Sporomiella* type (Fig. A5.4.1) (Ahmed and Cain 1972, Davis 1987). Of the remaining taxa, ASI041 (Endogonaceae type (Fig. A5.2.3)) and ASI029 *(Inocybe* type (Fig. A5.1.8)), are associated with soil , whilst types ASM004 *(Chaetomium/Lophitricus* type (Fig. A5.3.3)) and MUI004 *(Dichtyosporium* type (Fig. A5.7.3)) are associated with cellulose, and wood decay (Clarke 1994, Ellis and Ellis 1988).

The analysis of non-pollen microfossils produced much greater variation in the number and frequencies of form taxa recovered at each location. Several wholly new form types were identified in small quantities (1 or 2 examples) at individual sampling locations. Following van Geel (1978), as remarked earlier they have not been catalogued as part of the analysis, but are nevertheless represented in Fig 4.5 to demonstrate the distribution of taxa between the samples. The variation in NPF taxa compared to the pollen

taxa between samples is perhaps best illustrated by the differences in the types and frequency of non pollen microfossils taxa present in the poor graz-

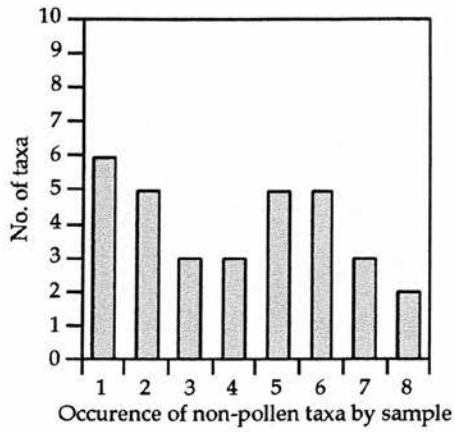


Fig. 4.5 Occurrence of spore taxa by sample at Meldon Hills

ing/pasture group (A, B, C, E, F).

Not only do the types of taxa present at different locations vary, but the proportions of individual taxa present also appear to fluctuate. For example, the dominant taxon (ASI010), varies from 2.3 % in sample C (M) to 15.3 % in sample E(M). Purely within the fungal sum this represents a fluctuation from 55% to less than 10%.

Despite the intersample variation in the fungal spore assemblages it is noteworthy that samples with a high frequency of dung from the improved pasture and the sheep pen -(D(S), G(S), H(I)) -contain increased frequencies of Sordariacious types ASM010 (*Tripterospora* type), ASM010 (*Podospora* type) and ASM029 (*Sporomiella* type The presence of these taxa and their known coprophilous nature suggests that these fungal spore types are good indicators of the presence of animal dung in the palaeoenvironmental record (Lundqvist 1972, Ahmed and Cain 1972).

It is difficult to interpret the meaning of the fluctuations in the fungal spore assemblage between samples from similar vegetational situations. It may be as a result of insufficient data collection or an inherent heterogeneity of fungal spore assemblages. However, the conclusion presented here is that the differences in the fungal spore assemblages represent the influence of microenvironmental differences between the sampling locations. This conclusion concurs with that suggested above (p.43) based on the work

of soil fungal ecology (Griffin 1972) and also that of Clarke (1994).

Palynodebris

The variation detectable in the palynodebris assemblage is principally between samples A (M), B (M) and the remainder. In samples A (M) and B (M) the quantities of all types of plant cells and amorphous organic matter are between two and three times higher than the remaining samples. Insect fragments are also slightly higher for A (M), B (M). Whilst it is difficult to interpret these figures as so little investigation of the palynodebris content of soils has been carried out, it is noteworthy that they are in the range of levels of palynodebris identified from the buried soils investigated at Balnuaran of Clava (Chapter 5), but much lower than the amounts of palynodebris recovered from peats at Trowie Loch (Chapter 6). It may be that the increased presence of Cyperaceae pollen and *Sphagnum* spores in samples A (M) and B (M) is indicative of wetter conditions at these sampling sites. Such wet conditions may retard the process of decomposition leading to increased levels of palynodebris. Alternatively, the plant species present at this location may be less susceptible to biological and mechanical deterioration, which has led to greater amounts of organic matter being preserved at this site. This result may also be a statistical anomaly due to the small number of samples examined in the study.

The palynofacies analysis thus indicates a more complex picture than that generated by the pollen analysis alone. Both the fungal spore assemblage and the palynodebris assemblage suggest a more complex division of the samples than the straightforward partition between those samples from the unimproved pasture and the remainder.

Despite the variation in the frequency and occurrence of non-pollen microfossils in the samples, examination of the data set indicates that samples from the unimproved pasture are dominated by *Calluna vulgaris* and Ericales pollen and fungal type ASI010. Samples D, G and H from the improved pasture and sheep pen contain higher levels of Poaceae, *Plantago* spp. and *Sordariacious* types ASM010 (*Podospora* type), ASM003 (*Tripterospora* type), and ASM029 (*Sporomiella* type). The data is further explored through the use of multivariate statistical techniques(described in Chapter 3.)

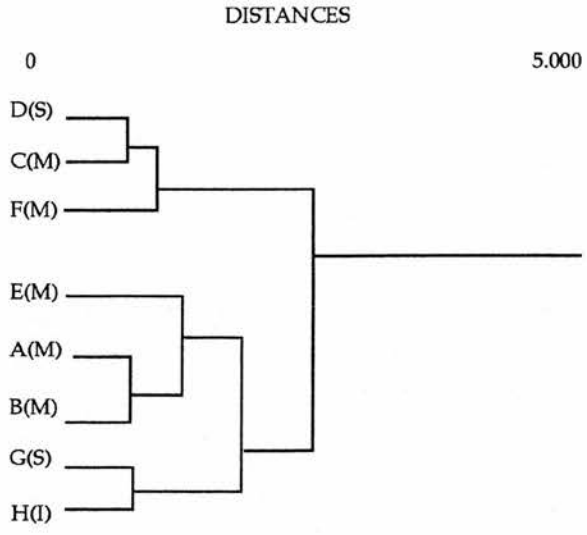


Fig. 4.6 Ward's method cluster analysis of selected pollen and non-pollen microfossils from Meldon Hill

Cluster analysis

The results of the cluster analysis using Ward's linkage on a reduced pollen and spore dataset produced two main clusters each with a number of outliers. The distances between splits are great and the resulting clusters are small. The first main cluster comprises samples C(M), D(S), and F(M) the second is composed of samples A(M), B(M), E(M), G(S) and H(I). The samples from the first group appear to cluster together because of their relatively high frequencies of Poaceae and low frequencies of fungal types ASI010 and ASM029 (*Sporomiella* type). The second cluster contains the remaining five samples. These samples resolve into two sub-groups one of which contains the samples from impoverished pasture (A, B and E). The other group contains two samples from the vicinity of the sheep pen and the improved grazing (G and H). The first group (A,B, E) are characterized by high frequencies of Cyperaceae and fungal type ASI010 and low frequencies of the dung and/or rotting vegetation taxa type ASM010 (*Podospora* type) and the coprophilous fungal type ASM029 (*Sporomiella* type). Samples G and H equally have relatively high frequencies of Cyperaceae, ASI010 and also types ASM029 (*Sporomiella* type) and ASM010 (*Podospora* type). The cluster analysis indicates a primary split in the samples related to the frequencies of Poaceae, Cyperaceae and of type ASI010. Further subdivision may be con-

nected to the frequency of taxa such as ASI010, ASM029 (*Sporomiella* type) and ASM010 (*Podospora* type). This suggests that soil wetness as indicated by the level of Cyperaceae as well as grazing pressure and dung frequency may be important influences on the composition of the palynofacies assemblage.

Principal components analysis (PCA)

The result of the PCA analysis (Table 4.6) was that the first four principal components covered almost ninety percent of the variance within the samples which indicates that the analysis is a robust simplification of the data (Birks and Gordon 1985). Conventionally, if the first three principal components cover 70% of the variance then the analysis is generally considered to be statistically meaningful (Birks and Gordon 1985). A plot of the factor scores for the first and second principal components produced two loose groupings or sets of samples which, whilst similar to the groups generated by the cluster analysis, have some significant differences (Fig 4.7, 4.8. and Table 4.7, 4.8).

Loadings for the first principal component produce two sets of samples slightly different from those from the cluster analysis. The first set comprises samples C(M), D(S), F(M) and G(S) which are all positively loaded for the first principal component. The second group, which is negatively loaded on the first principal component, comprises samples A(M), B(M), E(M) and H(I).

Two broad sets (similar to those from the cluster analysis) may be identified based on the second principal component. Positive loading for the second principal component produces a group composed of (A(M), C(M), E(M), F(M), D(S)). A second group negatively loaded for the second principal component comprises samples B(M), G(S) and H(I) .

If we examine the component loadings by taxon for the first two components an interesting pattern emerges. Positive values for the first principal component are related to grassland pollen taxa such as Poaceae, and other herbs such as *Plantago lanceolata,* Asteraceae lactucoideae and fungal types such as ASM029 (*Sporomiella* type) and ASM010 (*Podospora* type), ASM006, ASM007 and ASI021. Negative loadings on the first principal component are associated with Ericales and Cyperaceae and the spore types ASI010, ASI017 and ASM012

The second principal component seems to be measuring similar

	1	2	3	4	5	6	7
Percent	34.192	27.303	17.902	8.475	5.104	3.64	2.664

Table 4.6 Percentage of total variance explained by component for samples from Meldon Hills

Component score	1.00	2.00	3.00	4.00	5.00	6.00	7.00
A	-1.76	0.02	0.62	1.58	0.06	0.34	0.11
B	-0.94	-0.10	0.56	-1.71	-0.73	-0.73	0.97
C	1.35	0.65	0.78	0.84	0.41	-1.29	0.85
E	-0.20	1.45	-1.96	-0.08	0.14	0.18	0.28
F	0.42	0.48	0.38	-0.03	-1.43	-0.12	-1.88
D	0.73	0.19	0.81	-0.54	0.51	2.06	0.33
G	0.62	-1.89	-1.00	0.50	-0.79	0.17	0.51
H	-0.22	-0.79	-0.19	-0.57	1.83	-0.61	-1.17

Table 4.7 Component loadings for samples from Meldon Hills

Taxon	1	2	3	4	5	6	7
Ericales	-0.911	0.095	0.303	-0.068	0.15	0.159	0.127
Poaceae	0.874	0.29	-0.045	0.054	0.053	-0.379	0.037
ASM010	0.848	0.301	0.193	0.065	-0.049	0.381	0.03
ASI021	0.847	0.091	0.177	-0.117	-0.401	0.032	-0.259
ASI027	0.694	0.381	0.242	-0.488	0.251	0.094	-0.067
ASI010	-0.648	0.317	0.572	0.117	0.07	-0.176	-0.321
Calluna vulgaris	-0.613	-0.27	-0.067	-0.56	-0.46	0.097	-0.111
ASM003	0.609	-0.471	0.227	0.571	0.033	0.118	-0.12
Plantago lanceolata	0.187	-0.917	-0.178	0.151	-0.136	0.217	0.069
Cyperaceae	-0.344	0.861	-0.046	0.153	0.123	0.307	-0.074
Asteraceae lactucoideae	-0.214	-0.778	0.558	0.112	-0.027	-0.9	-0.126
ASM012	-0.267	0.663	0.147	0.397	-0.487	0.093	0.253
ASM007	0.012	-0.636	-0.755	-0.078	0.128	-0.044	0.021
Plantago spp.	-0.197	-0.558	0.792	0.036	0.095	0.057	0.096
ASM029	0.498	-0.138	0.719	-0.361	-0.017	-0.068	0.283

Table 4.8 Component loadings of selected taxa for the first seven principal components

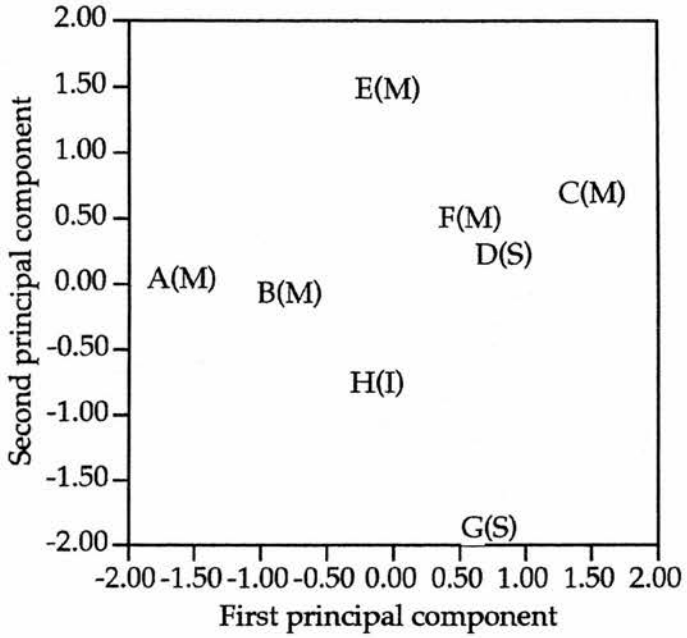


Fig. 4.7 Plot of samples along the first and second principal components

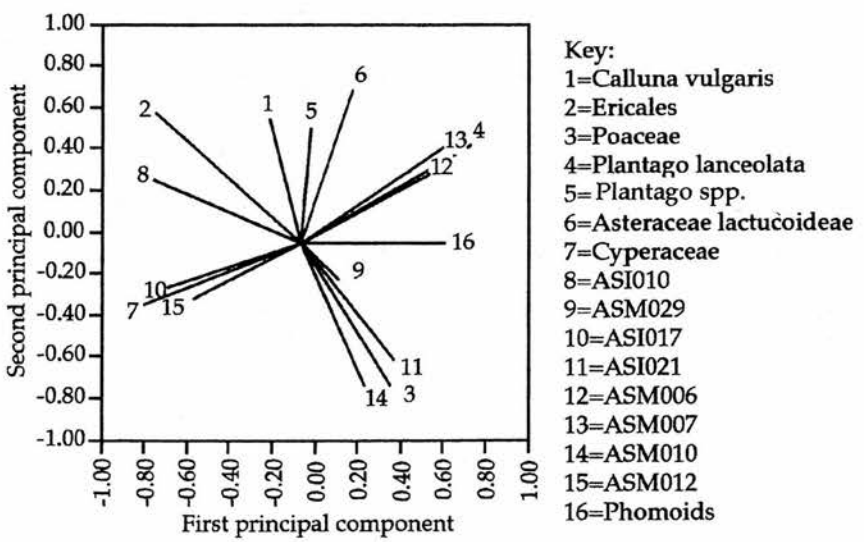


Fig. 4.8 Component loadings for selected taxa along the first two principal components

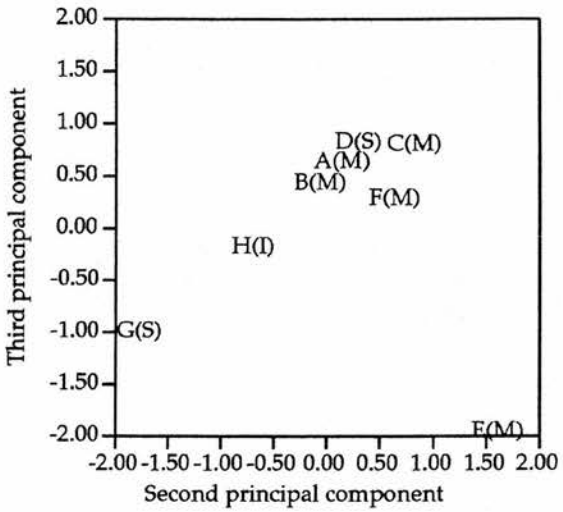


Fig. 4.9 Plot of second and third principal components for samples from Meldon Hills

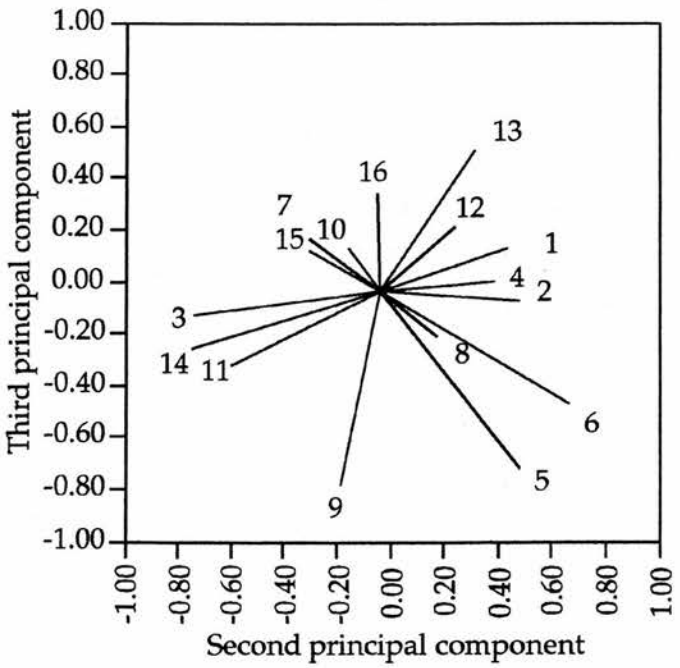


Fig 4.10 Plot of selected taxa component loadings for the second and third principal components for samples from Meldon Hills

variation to the first principal component. Positive loadings for the second principal component are shown by *Calluna vulgaris*, Ericales and herbaceous taxa such as Asteraceae lactucoideae and the *Plantago* spp. Negative loadings for the second principal component are largely shown by spore types especially types ASM029 (*Sporomiella* type), ASM010 (*Podospora* type), ASI021 (Fig. A5. 1.5) with Poaceae and Cyperaceae the only negatively loaded pollen taxa for this component.

The first principal component may possibly relate to the soil moisture gradient with wetter conditions indicated by the percentage of Cyperaceae, and drier conditions indicated by the percentage of Poaceae and other herbs especially *Plantago lanceolata.* The second principal component is perhaps more related to grazing pressure with negative values for Poaceae, Cyperaceae and fungal types associated with dung and/or rotting vegetation such as ASM029 (*Sporomiella* type) and ASM010 (*Podospora* type).

It is possible to investigate the variation in these samples further if the sample loadings along the third principal component are considered. Plotting the samples loadings for the second and third principal components produces a tight group of five samples (A(M), B(M), C(M), D(S), F(M)) with positive loadings for the both the second and third principal components. The remaining samples G(S), H(I), E(M) are outliers of this main group (Fig 4.9). Negative loadings on both the second and third principal component are related to the frequency of fungal types ASM029 (*Sporomiella* type) and ASM010 (*Podospora* type) and *Plantago* spp. and Asteraceae lactucoideae within the samples (Fig. 4.10). This produces a tight group of samples with low frequencies of fungal spore types ASM029 (*Sporomiella* type) and ASM010 (*Podospora* type) and the outliers G(S), H(I) which are negatively loaded for both components and sample E(M) which is positively loaded for the second and third principal components.

The third principal component therefore appears to relate to variation in the frequency of fungal types ASM029 (*Sporomiella* type) and ASM010 (*Podospora* type) in the samples. Both of these taxa are known to be coprophilous and it is tempting to link variation along the third principal component to dung frequency. The anomalous behaviour in this regard of sample D(S) from the sheep pen must however be noted. This result may be due to the the low frequency of type ASM010 (*Podospora* type) and the absence of type ASM029 (*Sporomiella* type) in sample D.

The numerical analysis of the pollen and fungal spore assemblage produced some worthwhile insights. The second and third principal components in particular appeared to relate to the degree of grazing pressure and dung frequency, as indicated by the frequencies of Poaceae, and fungal types ASM029 (*Sporomiella* type) and ASM010 (*Podospora* type). The groupings produced by both the cluster analysis and the principal components analysis suggest that other variables affected the composition of the non-pollen microfossil assemblage. It is speculated that the degree of soil wetness may be a particular factor in influencing the results.

Conclusion

Pollen data

The pollen spectra in the samples analysed in this study appear to be a robust indicator of the vegetation communities (in a broad sense) present at the sampling sites, a conclusion which concurs with many other studies of surface pollen data (Wright 1966, Anderson 1970,Tinsley and Smith 1972, Gaillard 1992, Tipping 1997). Small scale differences in land use between the sheep pen, the improved pasture and the unimproved pasture are indicated by variation in the frequencies of Poaceae and *Calluna vulgaris* between the samples. However, as the pollen evidence relates solely to the type of plants present in the environment, this evidence would not by itself demonstrate the function of the sheep pen, should a similar structure be found in the archaeological record. It would only be possible on the basis of this pollen evidence to discuss the general environment around the monument. The non-pollen microfossil evidence, particularly the presence of coprophilous taxa such as the Sordariacious taxa provides additional evidence for the presence of animals in the environment.

The role of NPF data in modern surface studies

One of the aims of the study was to examine whether the overall assemblage, in particular the fungal spore assemblage, correlated with local environmental differences. To assess this individual pinch samples were taken from a number of similar vegetation and land use types. Analysis of the palynomorph assemblages indicates that they show much greater variation in the number, frequency and types of fungal spore taxa between locations than is present in the pollen spectra. This heterogeneity in the non-

pollen microfossil spectra suggests that fungal spores are indeed sensitive indicators of microenvironmental variation, at least for the environment studied.

The heterogeneity of the sub-fossil fungal spore assemblage is similar to that found by modern soil fungi studies (Griffin 1972) and the sub-fossil studies of Clarke (1994). These have demonstrated that while fungal communities may be correlated with soil type and plant communities, the growth and sporulation of fungi at a particular point may be the product of a range of short lived phenomena that gives rise to apparent heterogeneity between closely spaced samples and vegetation types (*cf.* Chapter 5). Therefore, the spore record is reacting to variations such as wetness, type of litter, soil fauna etc. which have little impact on the pollen record but that may have profound implications on the amounts and types of fungal spore taxa recovered. By exploiting the sensitivity of fungal spores to microenvironmental change it should be possible greatly to increase the accuracy of palaeoenvironmental studies. Such an improvement will, however, rely on increasing the number of identifiable spore types.

The identification of a set of criteria indicative of the former presence of dung in the palaeoenvironmental record was reasonably successful. Fungal types ASM029 (*Sporomiella* type), and the Sordariacious types ASM003 (*Tripterospora* type), ASM010 (*Podospora* type) and type ASI027 were found at several sample locations and in particular at the sheep pen and improved pasture (D, G and H). This suggests an association between these types and samples with relatively high frequencies of animal dung. With further work on the identification of different fossil members of the Sordariaceae it may be possible to develop reliable indicators of animal dung in the palaeoenvironmental record.

The palynodebris data indicated that samples A and B had greater amounts of organic debris. It is postulated that this may be as a result of greater soil wetness leading to increased litter preservation though such a finding requires more work before it can be substantiated.

The use of a palynofacies approach in a modern day setting produced some interesting information. It suggests that fungal spore assemblages, despite difficulties of identification, are sensitive to the type of small scale environmental variation that is often of great interest to archaeologists. The presence of a number of types of Sordariacious and other microfossils in the samples identified by previous workers and by mycologists as being related to animal dung in the samples is encouraging (van Geel 1978, Clarke 1994, Lundqvist 1972).

Chapter Five: Balnuaran of Clava

Introduction

The following chapter discusses the use of palynofacies assemblages in the analysis of soil profiles from a number of burial monuments found in Strathnairn. These burial monuments consist of three cairns of Clava type dating to the early second millennium BC and a ring cairn of the later second millennium BC.

The chapter is divided into 3 sections. An introductory section describes in general terms the archaeological background to the Clava cairns, the aims and objectives of the palynofacies study and a brief discussion of the archaeological project of which this study is part. The introduction then continues with a description of the present day environment of the cairns at Balnuaran of Clava and the known pollen analytical studies that have taken place in this part of Scotland.

The second section presents the results of the palynofacies analysis of the monuments. This is divided by monument, with firstly a description of the monument and the sampling location, secondly the dating evidence and finally the palynofacies results.

The discussion section is also subdivided. The first subsection examines the role of palynofacies (particularly fungal spore data) in understanding the taphonomy of the deposits. This is followed by sections dealing with the environmental interpretation of each sampling location. Before, an overall environmental synthesis is made the dating and phasing of the various monuments examined is considered. The chapter concludes with an overall discussion of the use of palynofacies analysis in soil pollen studies.

Section 1

Clava Cairns: Archaeological background

The Clava cairns which form the subject of the present investigation are situated at Balnuaran of Clava approximately 7 km east of Inverness in the north of Scotland (Fig. 5.1). Currently in the guardianship of Historic Scotland, the area at Balnuaran of Clava contains three

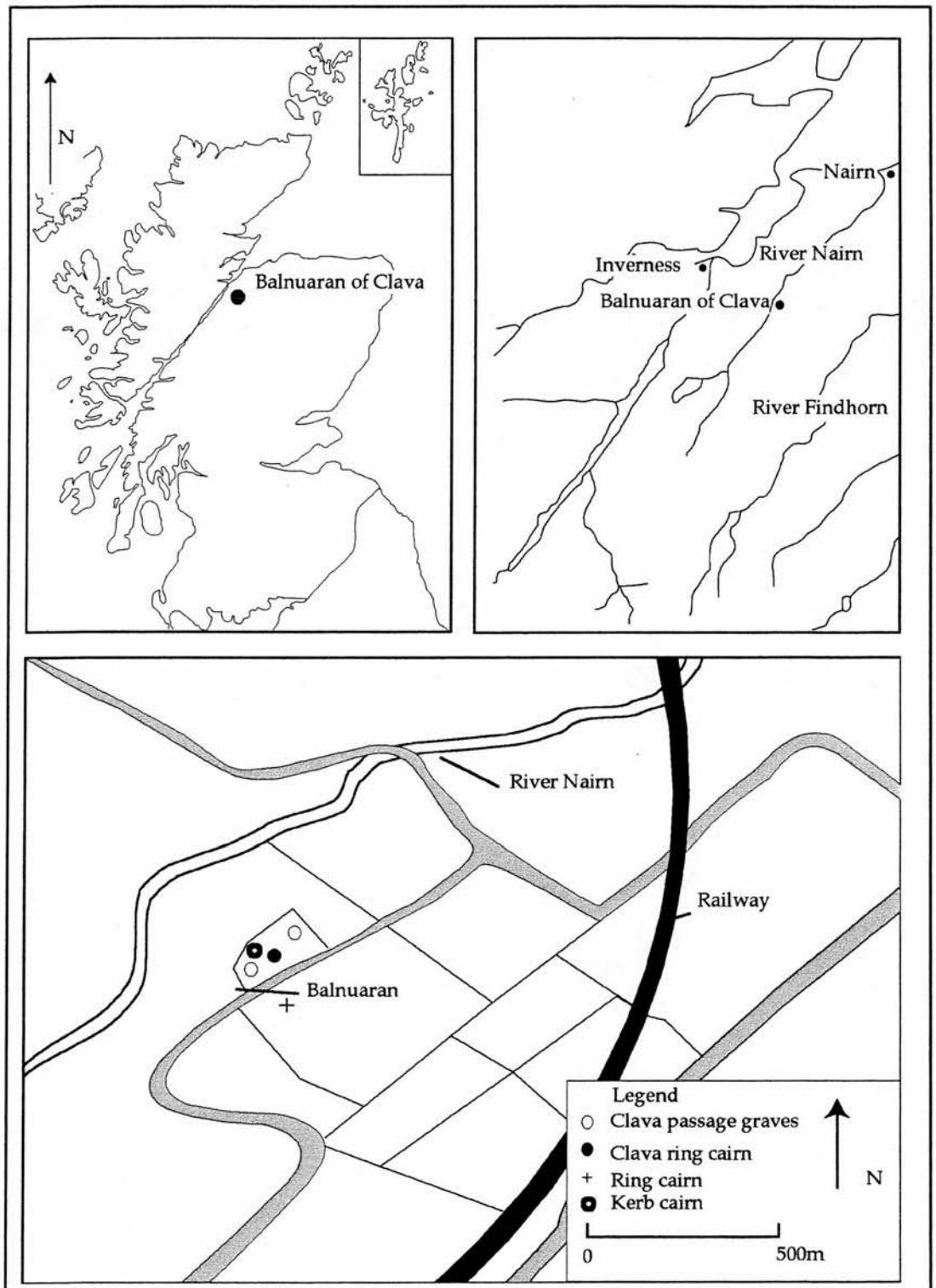


Fig 5.1 Location map of the study area at Balnuaran of Clava

Clava type cairns, forming the type site for the class of Clava cairns as a whole (Henshall 1963). The guardianship area includes two Clava type passage graves, Clava North-east and South-west, and a ring cairn, Clava Central. Within the guardianship area a small kerb cairn lies to the north of the South-west passage grave (Balnuaran North) and a small ring cairn lies just outside the guardianship area to the south (Clava South) (Fig 5.1).

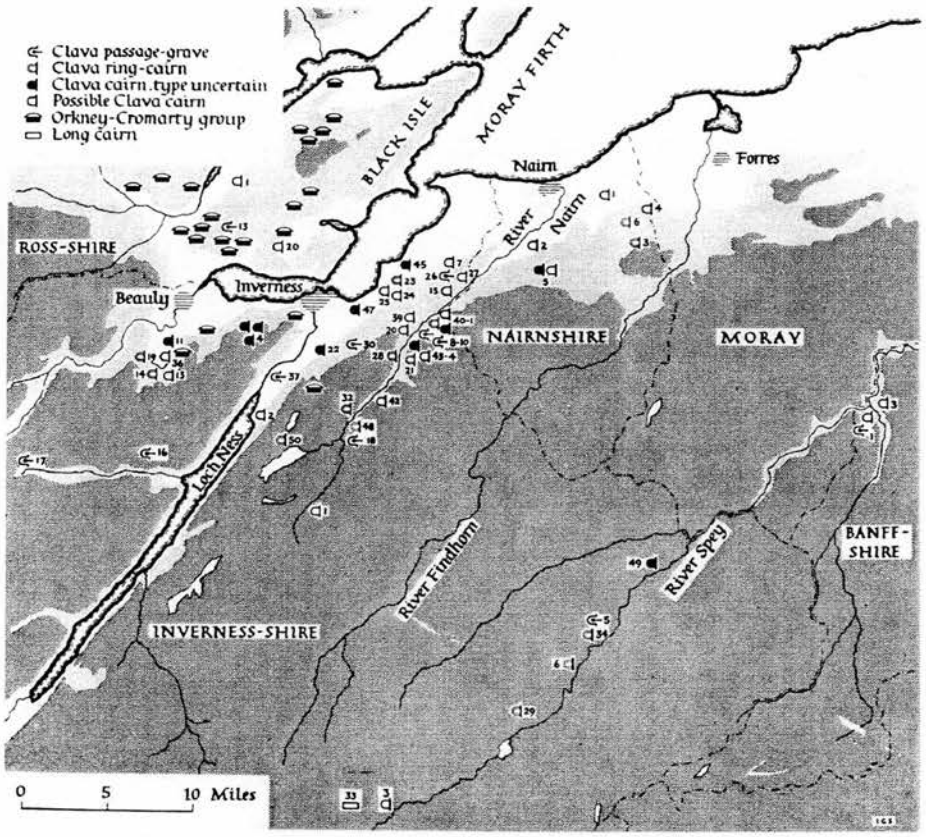
The history of the study of Clava cairns as a group is summarized in Henshall (1963) and by Bradley (forthcoming). The recognition that these were indeed a group of funerary monuments and not 'druids temples' (a robbed Clava cairn often looks like three concentric stone circles) occurred in the latter part of the nineteenth century (Henshall 1963). Much of the past research into the cairns has concerned drawing similarities between Clava type monuments and other burial and ritual sites in the British Isles (Piggott 1956, Henshall 1963, Burl 1972, Simpson 1996, Bradley 1996). However, a lack of independent dating evidence has hampered the drawing of accurate conclusions about the archaeological context of the monuments (Bradley 1996).

The primary distinctive feature of Clava cairns are the circle of monoliths that surround the central burial cairn, the graded orthostats that form the kerbs, and the use of rock art motifs (Appendix 5 Figs. 13-17) (Piggott 1956, Henshall 1963, Bradley 1996). The excavated monuments all contain evidence of burial, but whether these represent primary deposits as appears to be the case at Corrimony (Piggott 1956) or later reuse as at Balnuaran of Clava south-west (Henshall 1963, Bradley forthcoming) or both as at Raigmore (Simpson 1996) is unclear.

The distribution of cairns of Clava type is tightly defined, with the bulk of the monuments to be found in Strathnairn and the adjacent coastal plain, but with examples also being located in Strathspey and at the head of the Great Glen (Henshall 1963, Hunt 1987, Philips 1994). This distribution overlaps slightly with that of cairns of Orkney-Cromarty type in the area of the Beauly Firth, but is discrete from the distribution of recumbent stone circles in Buchan and Aberdeenshire (Fig. 5.2).

Generally speaking, passage graves of Clava type consist of three main elements: a central chamber and passage, a large circular cairn

Fig 5. 2 Distribution of Clava cairns and Orkney -Cromarty cairns, in the Inner Moray Firth and Black Isle (from Henshall 1963 Fig. 1)



and a surrounding stone circle (Henshall 1963) (Fig. 5.3 A). The central circular chamber is formed from contiguous orthostats graded in height to the south west, corbelling placed on these orthostats raises the height of the chamber, which appears in several cases, to have been roofed with a large capstone e.g. at Corrimony (Piggott 1956). Similarly, the passage is constructed from contiguous orthostats and its height is raised by dry stone walling e.g. Balnuaran of Clava South-west (Henshall 1963), and roofed by large slabs e.g.at Corrimony (Piggott 1956). The cairn surrounding the chamber consists largely of dumped river cobbles edged by an outer contiguous kerb of orthostats, again graded in height to the south west. This outer kerb is often surrounded by a low external rubble ramp, e.g. the cairns at Balnuaran of Clava (Piggott 1956). The cairn is enclosed by a large outer stone circle (Henshall 1963).

Clava type ring cairns are similar to the passage graves except that they lack a passage and roofed chamber. In these monuments an

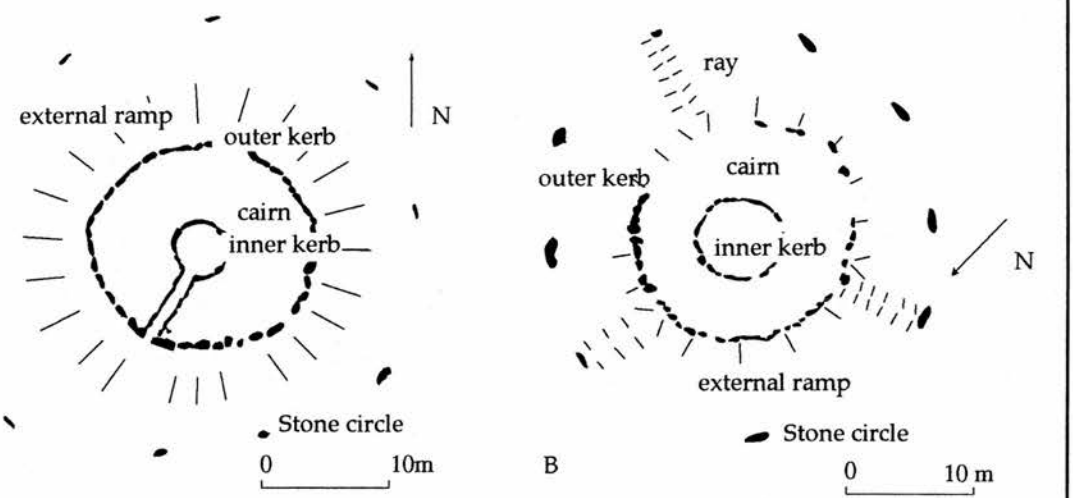


Fig. 5.3 Clava type passage grave (A), Clava type ring cairn (B)

inner and outer kerb of continuous orthostats, all graded in height to the south west, enclose a open chamber (Fig. 5.3 B). The space between the two rings is infilled with river cobbles and quarried stone slabs. Surrounding the cairn is an outer stone circle whose orthostats are also graded in height to the south-west. At some sites e.g. Culdoich and Balnuaran central, a external ramp of rubble is placed around the outer kerb. At Balnuaran central three 'rays' -thin lines of rubble run from the cairn to the surrounding circle.

Clava cairns as described above come in two types, passage graves and ring cairns. The relationship of the two types has been frequently debated (Piggott 1956, Henshall 1963, Burl 1972, Simpson 1996, Bradley forthcoming), but the absence of many recent excavations has meant that few concrete facts are known (Burl 1972). Piggott (1956) considered, on the basis of the overlapping geographical distribution and the architectural similarities of the two monument types, that they were both constructed and used during the Later Neolithic (Piggott 1956, Henshall 1963).

The ring cairn (Fig. 5.4) is a relatively common architectural form with a wide geographical and chronological spread throughout the British Isles (Ritchie and Maclaren 1972). Architecturally related monuments in Scotland include the recumbent stone circles of Aberdeenshire

(Henshall 1963, Ritchie and Maclaren 1972), ring cairns such as that at the Sands of Forvie (Ritchie and Maclaren 1972), and enclosed cremation cemeteries such as at Whitestanes (Ritchie and Maclaren 1972). A further category is that of kerb cairns many of which are related in form to ring cairns e.g. the small kerb cairn in the guardianship enclosure at Balnuaran excavated by Piggott (1956).

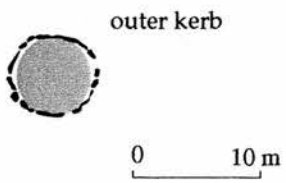


Fig. 5.4 Small ring cairn e.g. Balnuaran South.

Piggott (1956) thought that there may be a relationship between the ring cairns of Clava type and the recumbent stone circles but thought the relationship was not one " which can be expressed in direct or simple form" (Piggott 1956 p. 197). Henshall (1963) saw ring cairns further afield in Northern Scotland such as those in Aberdeenshire and Kincardineshire as degenerate forms of the Clava type (p.33), she also considered that the recumbent stone circles also derived from Clava type monuments (p.39).

Burl (1972) meanwhile saw a sequence of development from Clava type passage graves through Clava type ring cairns to recumbent stone circles. Barclay (1990) identifies the 'closure' of the central space through infilling at the ring cairns e.g. at Culdoich (Piggott 1956, Ritchie and Maclaren 1972) with other sites such as Balfarg and North mains (Barclay and Russell-White C.J. 1993, Barclay 1983). The Clava cairns therefore being part of a wider tradition of transformation in the Later Neolithic of enclosed space to closed mound (Barclay 1990). Simpson (1996), prefers to see Clava ring cairns as linked to the kerbed cairns and "as a response to local social, geographical and spiritual needs" (Simpson 1996 p.84). Bradley (forthcoming) returns full circle and suggests on the basis of the evidence of his excavation that Clava type passage graves

and ring cairns are parts of the same synchronous monument tradition, but is careful to note that further excavation and dating may shed more light on the relationship between the two monument types.

The other monument excavated by Bradley was a small ring cairn not of Clava type, which perhaps relates to the kerb cairn from the guardianship enclosure (Bradley forthcoming). Ring cairns and kerb cairns have been described by Burl (1972) and Ritchie and Maclaren (1972) as derivative forms of the Clava cairns. Simpson however has pointed out that such structures do not necessarily need to be late and cites the example of a kerbed cairn at Beech Hill, Coupar Angus which originates with Grooved Ware pottery and like Raigmore has later cists with food vessels (Stevenson 1995 in Simpson 1996).

Aims and objectives of the palynofacies study

The aims of the palynofacies study at Balnuaran of Clava were as follows: firstly, to describe the palaeoenvironment at the monuments prior to their construction; secondly to examine the role of palynofacies analysis in understanding the taphonomy of the deposits; thirdly to evaluate if palynofacies analysis was a valid methodology for the analysis of buried soils in archaeological deposits.

Recent excavations at Balnuaran of Clava and the survey project.

After discussing the background to the excavation of the Clava type cairns at Balnuaran of Clava and the archaeological survey of Strathnairn and the adjacent coastal plain, this sub-section then considers the geographical setting of the monuments.

The Clava cairns excavation project

The recent excavations of the three Clava cairns at Balnuaran of Clava are just the latest in a series of excavations which have attempted to understand these enigmatic monuments. The first excavations at Balnuaran of Clava took place in 1828 (in Munro 1924); the excavation of the central chamber of the South-west passage grave recovered evidence of a cremation and pottery which was illustrated by Lauder (Henshall 1963). From the description of the pottery, Piggott later suggested that

these pots were of Late Bronze Age date (in Henshall 1963, a very inspired suggestion as we will see below). A program of clearing the monuments was inaugurated in 1930 and 1931 by the Inspectorate of Historic monuments, which extended to partial excavation of the chamber of Balnuaran South-west, the rays of Balnuaran Central and the chamber and outer ramp of Balnuaran North-east (Barclay 1990). Further excavations occurred at Balnuaran central under the direction of Piggott (1956). Piggott excavated the central area of Balnuaran Central ring cairn and the surrounding stone circle (Piggott 1956) and the small kerb cairn.

Elsewhere Piggott excavated the passage grave at Corrimony, the passage graves at Druid temple, leys and Dores, Scaniport and the ring cairns at Culdoich, and the small kerb cairn at Balnuaran (Clava North) (Piggott 1956). In the absence of any finds or grave goods the results of these excavations did not shed much light on the chronology of the monuments.

Since Piggott's excavations in the fifties only two more Clava cairns have been excavated prior to the present project these are the Clava type ring cairns at Newton of Petty and Raigmore (Barclay 1990). The excavations at Raigmore were recently published by Simpson (1996). This indicated a complex sequence of activity at the site over several thousand years. Simpson identified three major phases of construction beginning in the fourth millennium BC and finishing at the end of the third millennium BC. No dates were obtained for the construction of the ring cairn, but it appears to have been constructed at some point between the middle and end of the third millennium BC. A series of pits with grooved ware dating to 2873-2509 cal BC (SRR-425), 2468-2298 cal BC (SRR-429), and 2466-2311 cal BC (SRR-428) predate the ring cairn whilst a series of cists with food vessels are inserted into it, one of which dated to 2290-1979 cal BC (SRR-428) (Simpson 1996). A further excavation of a Clava type ring cairn at Newton of Petty was also carried in the nineteen seventies but is currently unpublished. A report on this excavation will be included in Bradley (forthcoming) primary dates from this cairn also date to the end of the third millennium BC.

The project at Balnuaran of Clava, directed by Richard Bradley of the University of Reading, was a multi-disciplinary study, involving

excavation, field survey, soil science, macrofossil and soil palynofacies analysis. The Clava cairns importance lies in the diverse set of architectural traditions embodied in their construction, for example they incorporate stone circles, passage graves and ring cairns into one group of monuments, reflecting architectural conventions from many parts of the British Isles (Bradley 1996). It was to better understand the context of the cairns that the project was inaugurated.

The work at Balnuaran of Clava involved partial re- excavation of the three Clava cairns in the guardianship enclosure and of a fourth ring cairn not of Clava type situated approximately 100 m to the south (Fig 5.2). The study had three main aims: 1) to assess if the present day appearance of the monuments was the result of previous excavations and restoration work or whether the monuments were substantially intact; 2) to resolve the constructional sequence of the Clava type cairns, principally whether the different elements of the cairns; external ramps, cairns, kerbs, 'rays' and stone circles were constructed simultaneously or were added at a later date 3) to obtain radiocarbon dates for the monuments and to investigate the palaeoenvironment through an integrated programme of soil palynofacies analysis, soil micromorphology and plant macrofossil analysis (Bradley 1996). The soil micromorphological analysis was used to determine contexts suitable for dating by the AMS radiocarbon method (Bradley 1996). In addition, a field survey of the adjacent coastal plain and valley was used as the basis for a microtopographic study of the position of the Clava cairns within the landscape (Philips 1994).

The results of the excavations will be published elsewhere and this summary relies on unpublished reports, lectures and drafts provided by the excavator (Bradley 1996, Bradley forthcoming). To briefly summarize; the results of the excavations suggested that the three Clava type monuments in the guardianship area were constructed during the late third millennium or early second millennium BC (Bradley forthcoming) and the excavator suggests that their construction possibly occurred broadly synchronously (Bradley forthcoming). There is evidence from the Balnuaran North-east passage grave that the external ramp at this monument may have been constructed shortly after the construction of the cairn. At the South-west and Central cairns the external ramps at these

sites appear to have been constructed at the same time as the cairns (Bradley forthcoming). The later ring cairn to the south was found to be poorly preserved and dated to the end of the second millennium BC.

A field survey of parts of Strathnairn and the adjacent coastal plain was carried out as part of the project. Locational analysis by Philips (1994) indicated that Clava cairns are often situated so as to be close to water, in areas of good arable land and slightly hidden within the landscape. Field survey by the team from Reading University indicated that the monuments were associated with defined scatters of stone and flint tools (Watson and Bradley forthcoming).

The results of the locational analysis, together with the field walking evidence and the use of analogies from Neolithic Wessex (Thomas 1991), and the work of Bradley in Galloway and Argyll (Bradley 1991, 1994) led Philips to propose that semi-sedentary pastoralism was practiced by the people who constructed the tombs (Philips 1994). This interpretation of the economy was based on a theoretical approach which saw the monuments as part of system of linear routes leading from the coastal plain to the high ground at the head of Strathnairn (Philips 1994). In this interpretation Clava cairns form part of a seasonal route along which herds of animals would be moved as part of a annual round (*cf.* Bradley 1991, Bradley *et al.* 1993). This largely theoretical interpretation derived as it is without consideration of the environmental and other evidence from elsewhere in Scotland (e.g. Whittle 1986, Barclay 1997, Fairweather and Ralston 1993) will be considered below in the light of the palynofacies analysis from the monuments.

Physical background

Balnuaran of Clava

The sites investigated are situated in the valley of the River Nairn approximately 7 km to the east of Inverness at 100m O.D. (NGR 751 437). The Nairn is a fast flowing river that rises in the Monadhlieth mountains and flows north emptying into the Moray Firth at Nairn.

At Balnuaran of Clava the valley is approximately 0.5 km wide and flat bottomed with smooth sloping sides. The geology of the area

around the site is of Devonian middle red sandstones (Fig. 5.6 C). The bedrock is overlain by alluvium and the cairns occupy a gravel ridge situated on the lowest of a number of a suite of terraces (Simpson and Davidson 1995 (Fig 5.6 A). The origins of these terraced features are complex, but they appear to be glaciogenic (Merritt 1990). The soils as indicated on the 1:63630 scale soil map of the area are free draining podzols of the Corby, Boyndie, and Dinnet series (Fig 5.6 B) (Macauley 1976, Simpson and Davidson 1995).

The climate of this part of the Moray Firth is comparatively favourable considering its northerly latitude. Levels of rainfall are relatively low in comparison with areas to the west such as Wester Ross and the north such as Caithness (Plant 1968), and the long summers give prolonged periods of sunshine similar to coastal regions of East Lothian (Plant 1968).

The combination of soils and climate means that much of the Nairn valley floor is one of the more favoured areas for cultivation in Invernesshire and Nairnshire. The land is rated by the Macaulay Land Use Research Institute as class 2, (Futty and Towers 1982). Presently, pasture and hay making are the dominant land use in the vicinity of Balnuaran of Clava but nearby barley and other arable crops are grown.

The guardianship area is separated by a wall from the surrounding agricultural landscape. Within the guardianship enclosure a open copse has been planted with trees of sycamore and hawthorn. The immediate surroundings of the guardianship area are dominated by pasture with some small patches of gorse,broom and heather scrub. Balnuaran of Clava south is situated in such a patch of scrub. Nearby to both east and west are extensive areas of heather moorland. The vegetation of Strathnairn is characterized by McVean and Ratcliffe as of predominately pine forest with birch and oak (1962). Whilst Tipping (1994) would see it as predominately part of the birch/hazel and oak woodland stretching from the Dornoch Firth to Aberdeenshire. Pollen analyses at Kingsteps Quarry (Nairn), (Knox 1954) and Strichen (Buchan) (Durno 1956) suggest that pine was not an important component of the Moray Plain after the beginning of the Atlantic period. Present day riverine environments in the vicinity of Inverness where not used for pasture are often

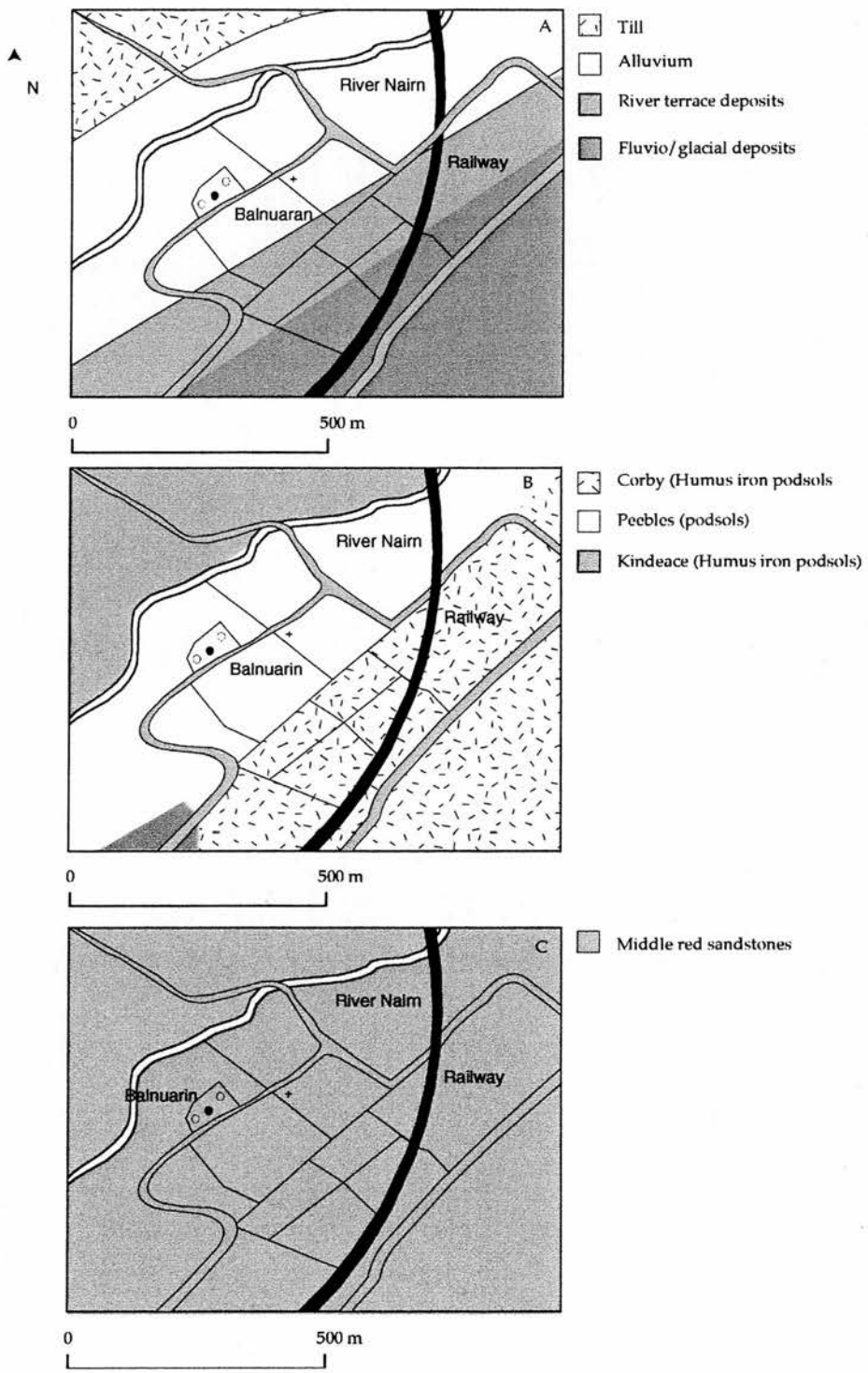


Fig. 5.5. A.) Simplified drift geology, B.) Simplified soil types, C Simplified Geology at Balnuaran of Clava (A and C after British Geological Society (1997). B after Macauley 1976)

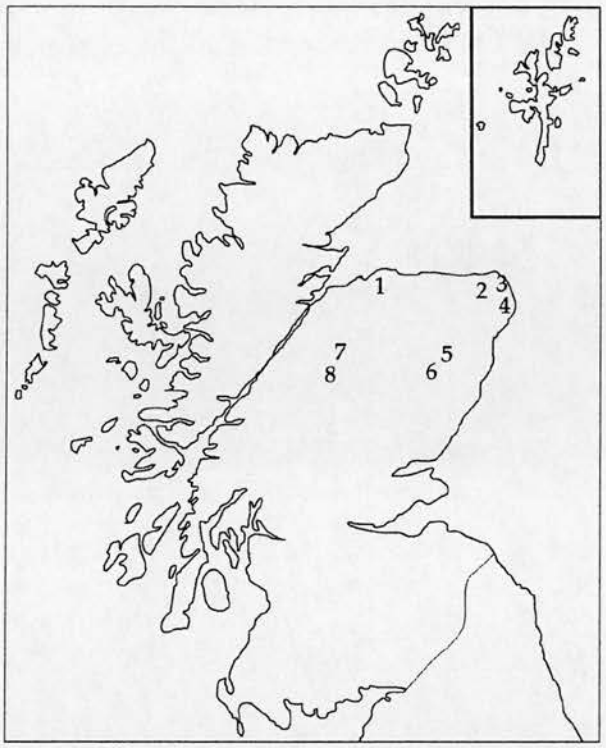
given over to small alder woods and hazel shrubs (Barron and Bush 1975).

Vegetation History

A perusal of the recent review of Scottish woodland history by Tipping indicates that after the pioneering work of Durno in the 1950's and 1960's palynological research of the later part of the Holocene in the archaeologically important areas of the Inner Moray Firth, Buchan, and Banff effectively ceased (Tipping 1994). The aim of this review is briefly to discuss the probable state of the cultural landscape in this part of Scotland, around the beginning of the second millennium BC. This review will draw on the reviews of north east Scottish woodland history by Gunson (1975), Edwards (1997b) and Tipping (1994), and the work of Edwards at Braeroddach loch and Loch of Davan in Upper Deeside (Edwards 1979, Whittington and Edwards 1997) (Fig. 5.6).

Gunson divided north-east Scotland into three areas: 1)Upper Deeside, Speyside and the Cairngorm glens; 2) the mountainous plateau of the Eastern Grampians; and 3) Lower Deeside, Aberdeenshire and Buchan coastal area. Of these groups, if we follow Tippings 1994 reconstruction of woodland types, the Inner Moray Firth would appear most similar to area 3. This discussion will therefore use material from Gunson's area 3 in its discussion of the possible vegetation background of the inner Moray Firth, during the early second millennium BC.

In area 3 which probably includes the inner Moray Firth a sequence of birch woodland, followed in turn by birch/hazel woodland, birch/hazel/oak/elm and immediately prior to widespread human intervention in the landscape by birch/oak/elm/alder woodland is found at the sites investigated (Knox 1954 (Fig. 5.5 (1)), Durno 1956 (Fig. 5.5 (2,3,4)), Edwards 1979b, (Fig 5.5 (5,6)), Gunson 1975, Tipping 1994). The only detailed radiocarbon records for the area under consideration are those from Braeroddach Loch and Loch Davan in Aberdeenshire (Edwards 1979b). However, Edwards' sites are located close to the boundary with the upland pine/birch forests of the Cairngorms and although they are the closest in terms of vegetation type to the Inner Moray Firth they may not be entirely analogous to the situation at Balnuaran. The following discussion is therefore to provide a broad background to the prob-



Key (see text for references)
1 =Kingsteps Quarry, Nairn
2 =Strichen
4 =Rora
3 =St Fergus
5 =Braeroddach Loch
6= Loch Davan
7= Loch Pityoulish
8= Loch Garten

Fig. 5.6. Pollen sites mentioned in the text.

able vegetation of the Inner Moray Firth.

The diagrams from Braeroddach Loch and Loch Davan show a pattern of small scale and relatively short duration (*c.* 2-500 yrs) clearance and regeneration (*c.* 2-500 yrs) from *c.* 4100 BC onwards (Whittington and Edwards 1997). From the Middle Bronze age onwards human activity becomes prolonged and major woodland reduction occurs at *c.* 1350 BC (Whittington and Edwards 1997). This is similar to the pattern in Fife at Black Loch, although a major decline in woodland occurred somewhat earlier at Black Loch *c.* 1970 BC (Whittington, Edwards, and Cundill

1991). By analogy with these sites, the area at Balnuaran of Clava in the inner Moray Firth woodland would have been undergoing periodic clearance/regeneration episodes throughout much of the fourth and third millennium BC.

It is also perhaps worth mentioning the work of O'Sullivan in Strathspey (1974a, 1974b, 1976). Strathspey is closer to the inner Moray Firth, but its woodland is more dominated by pine and birch woodland than would appear to be the case at the coast. The middle Flandrian (defined by O'Sullivan as *c.* 6650-3000 BP), is characterized as a period of woodland with varying fluctuations of pine, birch and alder with some oak and hazel (O'Sullivan 1976) Human interference with vegetation as recognized by O'Sullivan does not begin at Loch Garten until *c.* 3600 BP (O'Sullivan 1974b), and at Loch Pityoulish until *c.*3000 BP. This suggests that at the time of the construction of the Clava cairns *c.* 2000 BC at Balnuaran the woodland in Speyside largely comprised a mixed birch-pine alder forest that had yet to see major clearance episodes (O'Sullivan 1974b).

At the time of the construction of the Clava cairns at Balnuaran it is impossible, in the absence of a regional pollen diagram, to say whether woodland in the inner Moray Firth, was undergoing major decline by the beginning of the second millennium BC as at Black Loch in Fife, or whether clearance was intermittent, as at Braeroddach Loch. If Tippings (1994) reconstruction of woodland distribution is broadly correct then the lower reaches of Strathnairn would originally have had a mixed birch-hazel oak woodland prior to *c.* 3000 BC; after this time we can only speculate as to the degree of clearance and regeneration that occurred. The local nature of the soil pollen analyzes at Balnuaran will not answer the overall question of woodland change in Strathnairn which will have to await a regional pollen diagram.

Conclusion

Despite the large literature on the topic of the Clava cairns, surprisingly little is known about the monuments themselves. In particular the context of the monuments in the past landscape and the specfic date of their construction, though they are assigned to a broad chronological period. The aim of the recent excavations was an attempt to answer

some of these questions. This study used new methodological approaches in an attempt to understand both the nature of the deposits, the record of the environment preserved within them and also the types of activities practiced by the society which constructed them.

The study of the palaeoenvironment both in the important region of the Inner Moray Firth and of the Clava cairns is in its relative infancy. So too is the use of palynofacies data in the analysis of buried archaeological soils and archaeological deposits. The excavations here offer the opportunity to test the procedures and methodologies employed in palynofacies analysis in a number of differing archaeological contexts. The aim is to assess what benefits to the study of human palaeoecology, and cultural landscapes that the technique of palynofacies may hold.

Section 2: Results

Balnuaran of Clava South-west (Clava type passage grave)

Site Description.

Balnuaran of Clava South-west is a large (*c.*12m diam) passage grave in the Clava tradition (Fig 5. 7, Appendix 5 Figs. 13.1, 14.2) (Henshall 1963). As discussed above it has been excavated at least twice in the past once in the nineteenth and once in the twentieth century. The recent excavations by Richard Bradley of Reading University were of the external ramp and the central chamber (Fig 5.7). The aim of the excavations of the central chamber was to better understand the nature of the remains described by Kennedy (in Barclay 1990). The excavations of the external ramp was to see if this ramp was an integral part of the monument or a later addition.

Two short sequences were obtained from sealed deposits beneath this monument; the first, Location A was from a small area of undisturbed fill in the central chamber; the second, Location B was from beneath the external ramp. In the following sub-section the results from Locations A and B are discussed in turn. Firstly, a description of the sampling site and sam-

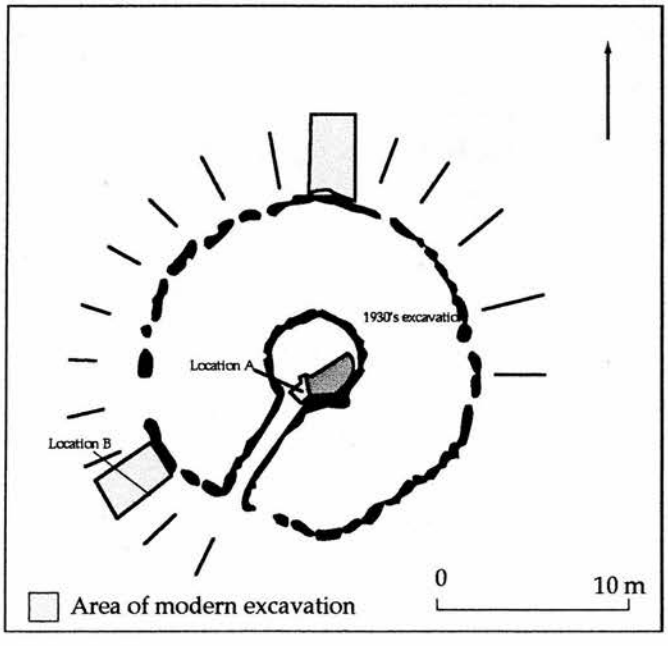


Fig. 5.7 Position of excavated areas and soil palynofacies sampling locations at Balnuaran of Clava South-west

pling methodology are given. This is followed by the results of dating where applicable and finally the results of the palynofacies analysis are outlined.

Location A : Sampling location and soil profile description

This sample came from close to where the passage enters the chamber. At this location there was sufficient of the fill of the deposit remaining to obtain two samples one for soil micromorphological analysis and one for soil palynofacies analysis. Sampling was by Kubiena tin, further subsampling took place in the laboratory as described in Chapter 3.

The soil profile at this location consists of three horizons *c.* 65 mm thick (only the top 50 mm were sampled for soil palynofacies work however) (Fig. 5.8). The following description of the soil profile follows that of Simpson and Davidson (1995, 1997). The upper horizon (Horizon 1) is an organo-mineral A horizon typical of a podzolic soil, which has been subject to burning. Horizon 2 is a grey iron depleted mineral horizon typical of podzol E horizons (Simpson and Davidson 1997 p.4). A third horizon (Horizon 3) was also recognized during the soil micromorphological analysis which was recognized on the basis of "slight differences in groundmass" it was suggested that this was a later added deposit which overlay and penetrated Horizons 1 and 2 (Simpson and Davidson 1997 p.4). During the pollen analysis sieving of the deposit produced a number (*c.*30) of small (*c.* 5-10 mm diam) fragments of burnt bone from the top 25 mm of the profile.

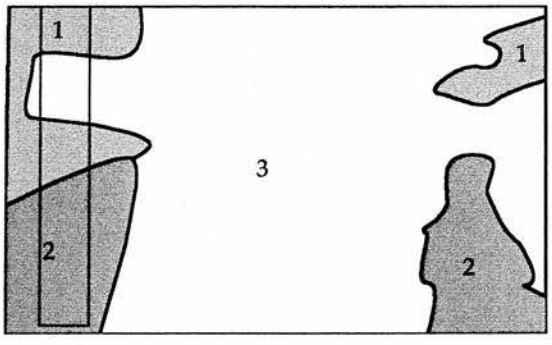


Fig. 5. 8 Soil profile at Location A (Key: 1= Horizon 1, 2= Horizon 2, 3= Horizon 3) (After Simpson and Davidson 1997 approximately 2/3 thirds actual size), inset box indicates area sampled for pollen

Radiocarbon dating.

Five radiocarbon dates were obtained from small fragments of charcoal recovered from the deposits found in the chamber. As described in Chapter 3 dates were obtained using the AMS radiocarbon method (Aitken 1990). All dates from the excavation are tabulated with lab nos. in Appendix 9.

AA-21251 2740± 55 uncal BP 2 σ 1010-810 cal BC

AA-21252 2770 ± 55 uncal BP 2 σ 1050-820 cal BC

AA-21253 2790 ± 60 uncal BP 2 σ 1100-820 cal BC

AA-21254 2765 ± 60 uncal BP 2 σ 1050-810 cal BC

AA-21261 2855± 70 uncal BP 2 σ 1260-840 cal BC

The criteria used to decide which deposits to date was based on the evidence of the soil micromorphological analysis which initially suggested that the deposits in the chamber represented an *in-situ* undisturbed ground surface (Simpson and Davidson 1995). These dates probably relate to the reuse of the chamber as described by Henshall (1963). No other radiocarbon dates have been obtained for this monument. The radiocarbon dates and the soil micromorphological analysis will be discussed further below in the light of the results from the palynofacies analysis, and the excavation.

Location A: Local Palynofacies assemblage zones. Pollen preservation and fungal hyphal analysis

The sequence was divided into two LPfAZ on the basis of changes in the main pollen, non-pollen microfossil and palynodebris spectra. Several samples in this assemblage were dominated by burned *Corylus type* pollen. Burning was identified by the criteria laid out by Andersen (see Appendix 8), and by comparison with experimentally burnt modern *Corylus type* pollen (1988) (Appendix 5 Figures 11.2-11.5). Because of the over representation of burned *Corylus type* pollen, two pollen diagrams are provided for comparative purposes at this sampling location; one based on the sum TLP-burnt *Corylus type* (Fig 5.9) and the second based on TLP (Fig 5.10), pollen concentration data is presented in Fig 5.11, N.B. the non-pollen microfossil diagram is still based on TLP (Fig. 5.12). A detailed breakdown of minor pollen taxa is given in Table 5.1, and minor fungal taxa in Table 5.2.

LPfAZ SWPG A1. (20-50 mm)

This zone is defined by burned *Corylus type ,Corylus* type, Poaceae, fungal spore types ASM038, ASM041 (Figs. A5. 4.6, 5.2), intermittently high levels of charcoal fragments (especially 35-45 mm) and lower levels of hyphal fragments (Fig. 5.12). The ratio of pollen to fungal and other non-pollen palynomorphs (hereafter referred to as NPF) shows that pollen dominates this assemblage accounting for over 50% of the recovered palynomorphs within the samples of this zone. The proportion of NPF to pollen varies down the sequence, and there is a decline in the relative proportions of NPF at samples 20-25 mm and 35-45 mm. This decline in the proportion of NPF at 20-25 mm and 35-45 mm is a result of the low raw counts of fungal spores at these levels. Pollen concentrations increase in samples 35-45 mm and 20-25 mm as a result of the influence of *Corylus* type pollen (Fig 5.9). Sample 45-50 mm is included in this group but has lower levels of burnt *Corylus* type pollen, charcoal and poorer pollen preservation than the above samples.

LPfAZ SWPG A2 (0-20 mm)

This assemblage zone is defined by the decline in frequency of burnt *Corylus* type and *Corylus* type pollen after 20 mm, there is also a reciprocal rise in the amount of Pteropsida and *Polypodium vulgare.* In LPfAZ SWPG A2 there is a decline in fungal spore types ASM038, and ASM041 and rises in fungal spore types ASM029, ASM001, ASM004 and ASI041 (Figs. A5.4.1, 3.1, 3.3, 2.3) and *incertae cedis* types IC008, IC009 (Figs. A5. 8.1,8.2) (monolete spores ?). In addition there is a increase in the amount of palynodebris especially in sample 5-10 mm, and in the number of hyphal fragments observed. Levels of NPF are higher within this zone at *c.*50% of the overall discrete microfossil frequency.

Pollen Preservation measures

The results of the tests for the reliability of this sequence are unfortunately not internally consistent. Different measures give differing responses as to the degree of reliability that can be inferred (Fig. 5.13). This suggests that an unusual set of taphonomic processes, have operated on the deposit from which these samples were obtained.

Pollen concentrations are highly variable within the sequence.

Samples 0-5 mm, and 5-10 mm have very high pollen concentrations, preceding a sudden drop in pollen concentration at 10-15 mm; thereafter values fluctuate to the base of the column, especially in sample 35-45 mm where pollen concentrations rise, due to the over representation of burned *Corylus* type pollen (Fig. 5.11). Pollen concentration return to lower values in sample 45-50 mm.

The ratio of TP:TP+indet remains relatively constant at around 0.9 with only minor fluctuations, which suggests that pollen spectra within the profile may not have undergone excessive distortion. The use of the TP:TP+S ratio graphically demonstrates the low values of spores in samples 20-25 and 35-45 where values for this ratio in excess of 0.9 are observed. Values of around 0.7 for this ratio are recorded in sample 0-15 mm and again at sample 30-35 mm. Tipping *et al.*, suggest a lower cut off point for this ratio of around 0.66 below which pollen spectra are unreliable (Tipping, Carter, and Johnston 1994). The high values of the TP:TP+S ratio highlight samples 20-25 mm and 35-45 mm: this measure apparently indicates that these are "well preserved" and this point will be discussed further below.

Using measures based on the numbers of taxa present and the ratio of taxa numbers TP:TP+S to assess reliability there is an inverse pattern to that described by the concentration data. There are relatively high levels of taxa (between 16 and 17) until 20-25 mm, where there is a decline to only 11 taxa; this level has a high proportion of burned *Corylus* type grains. Thereafter, numbers of taxa recover slightly at 25-30 mm and 30-35 mm but decline again at sample 35-45 mm to 10 taxa. This is again a level with a large number of burned *Corylus* type grains. The graph of taxonomic ratios (TP:TP+S) remains constant at around 0.8 for much of the sequence but declines below 0.8 at samples 20-25 mm and 35-45 mm, indicating (contra the pollen: spore concentration ratio) that preservation worsens at these levels.

The proportion of well preserved pollen declines down the sequence from nearly 30% of pollen in samples 0-15 mm, to under 10% in sample 45-50 mm. Within the determinable pollen there are fluctuations within the major preservation classes, corroded pollen is the dominant type of deterioration in samples 0-15 mm, crumpling is the dominant type of deterioration in samples 15-45 mm, and corrosion becomes dominant again in sample 45-50 mm. Indeterminate pollen of all types is at its highest in the

samples dominated by burned *Corylus* type, aside from these samples indeterminate pollen appears to be highest in samples 0-5 mm, 5-10 mm and 45-50 mm. The high concentrations and amount of well preserved pollen in samples 0-15 mm would indicate that these have the best pollen preservation, whilst on these measures samples 20-50 mm have the worst pollen preservation.

Within the major taxa it is possible to see the above pattern replicated. Preservation is generally poor in both Poaceae and *Corylus* type pollen with the maxima of well preserved pollen for both of these taxa at less than 10% in sample 0-5 mm and preservation subsequently declines down the profile. For *Corylus* type type pollen, corrosion is the dominant type of degradation in the top 0-15 mm thereafter burned *Corylus* type is dominant until sample 45-50 mm where both corrosion and degradation are the main forms of deteriorated pollen. Poaceae grains appear to be more susceptible to crumpling and this forms the dominant class of deterioration. The levels at 20-25 and 35-45 mm are again anomalous with a slight increase in the level of well preserved Poaceae pollen. Pollen preservation is apparently better in *Calluna vulgaris, Betula* and *Alnus* as there is a higher proportion of well preserved pollen in all of these taxa. In these cases however the sample size is low in comparison with Poaceae and *Corylus* type and may not therefore be significant.

From these analyses it is possible to see that the use of taxonomic ratios for the analysis of reliability of pollen spectra may be misleading if the pollen spectra are biased by over representation of any one taxa. This data set is unusual in that samples between 20-45 mm, have low levels of well preserved pollen and relatively low pollen concentrations indicating poor preservation, but they also have low levels of spores contra what one would expect.

The work of Casparie and Groenmann van Waateringe (1980), Havinga (1964) and Waterbolk (1958) suggests that there is differential preservation of spores in soils and that this leads to their over representation in poorly preserved deposits. The use of ratios based on pollen to cryptogrammic spore ratios, are only useful therefore, in situations where spores have formed part of the initial vegetation, and Dimbleby's criticism of the use of Pteropsida in particular as a measure of soil pollen reliability, is confirmed by this study (Dimbleby 1985). For this deposit the best indicators of

relative pollen preservation were the number of taxa/ level ratio, and pollen preservation classes of both determinable and indeterminable grains. Using these measures samples 15-50 mm appear to be less well preserved than 0-15 mm.

Pollen preservation measures indicate that this deposit has undergone a complex sequence of taphonomic processes. The use of these measures however suggests that this sequence has not been significantly biased by differential pollen preservation due to biological or chemical activity. As will be explained in detail below this deposit is thought to have resulted from human deposition of sediments into the chamber after its initial period of use.

Hyphal frequency analysis

Only two samples were examined in this study for hyphal frequency (0-5 mm and 30-35 mm) (Fig 5.14). The frequency diagrams indicate that the dominant soil fauna at this location was that of Oribitei, as is shown by the large values of short hyphal fragments.(Andersen 1979, Andersen 1984). This is consistent with the results of the soil micromorphological analysis which demonstrated that the deposit at this location had undergone little in the way of bioturbation (Simpson and Davidson 1995).

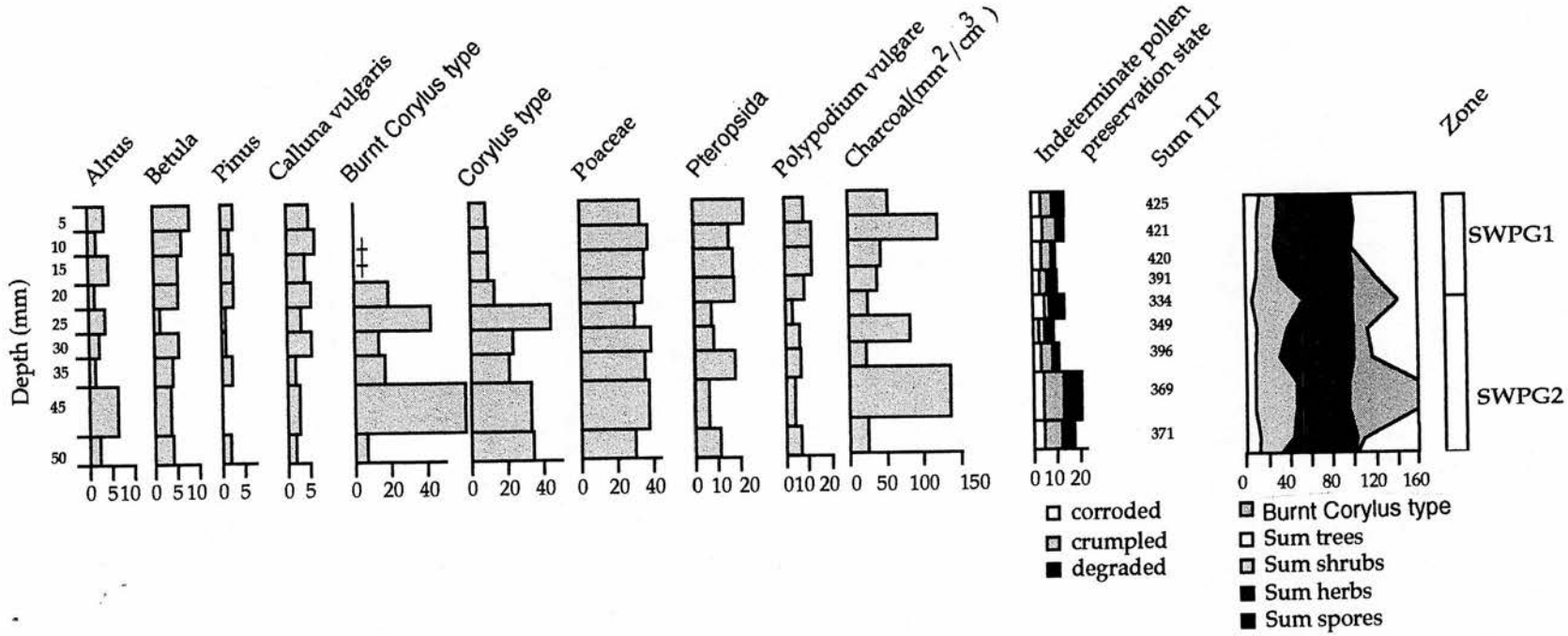


Fig. 5.9 Location A percentage pollen diagram, (Σ_{poll}=TLP-burned Corylus type), (Σ_{indet}=TLP+indet)

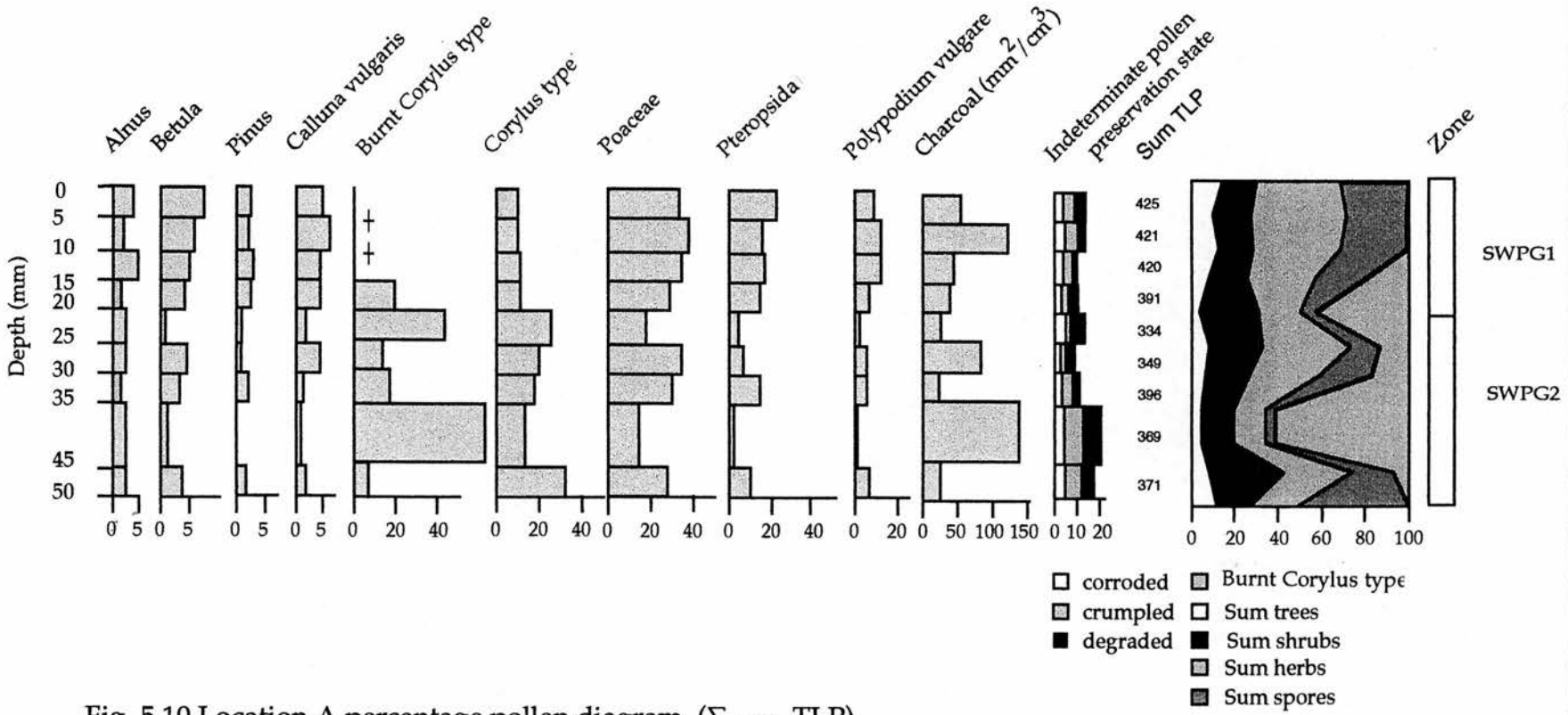


Fig. 5.10 Location A percentage pollen diagram, (Σ_{poll}=TLP),
+=<2%

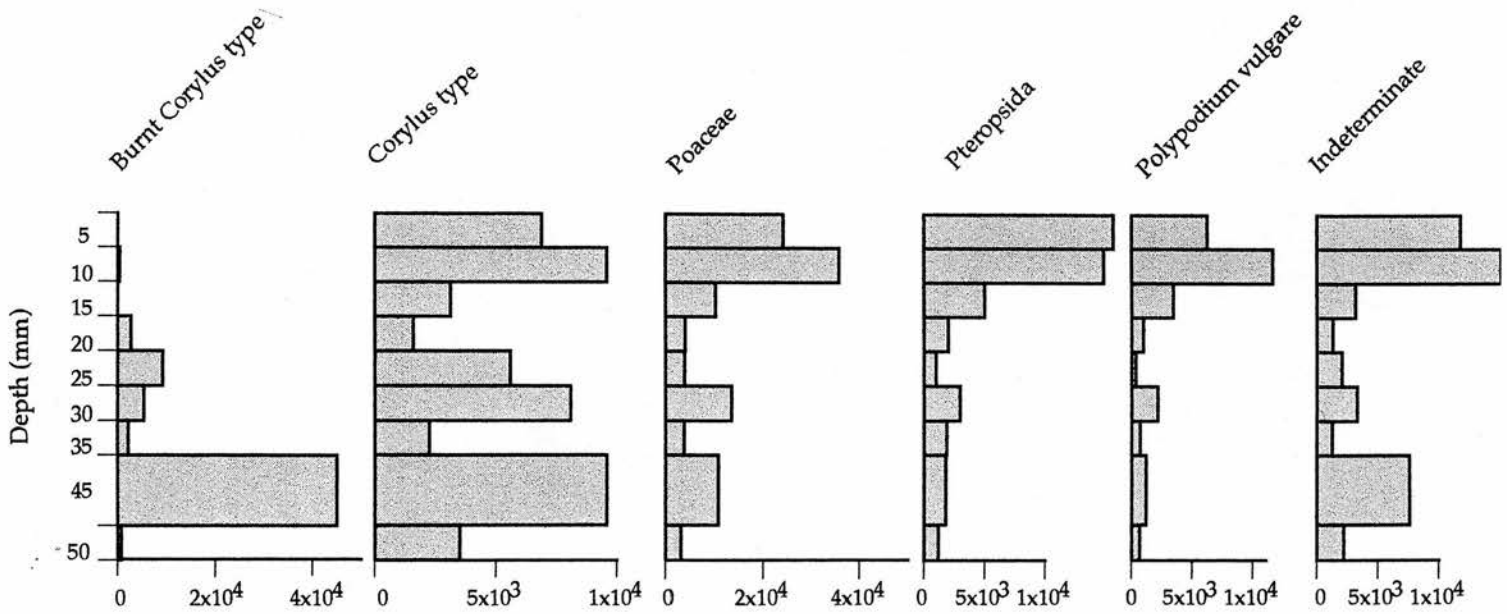


Fig. 5.11 Location A pollen concentration (grains/ cm^3)

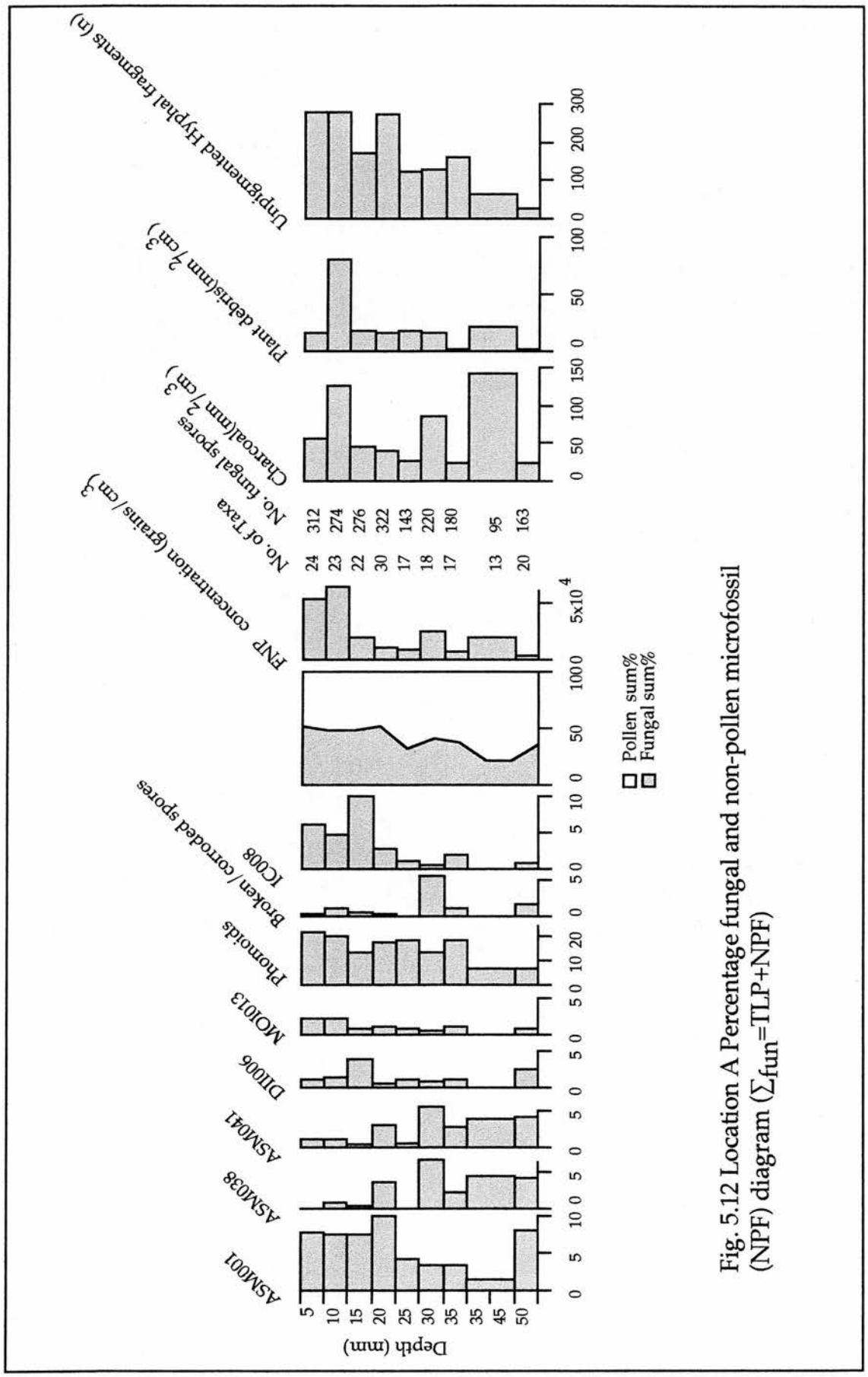


Fig. 5.12 Location A Percentage fungal and non-pollen microfossil (NPF) diagram ($\sum_{fun}$=TLP+NPF)

Sample	5	10	15	20	25	30	35	45	50
Pinus	11	9	12	9	2	3	8		7
Quercus	2							3	3
Ulmus			1	3		1			
Ericales	4	6		2			1	2	
Salix	2		2	1				1	
Alchemilla type		1							1
Artemisia			1				1		
Chrysosplenium	1								
Caryophyllaceae			1	1					
Chenopodiaceae	1								
Asteraceae lactucoideae	7	4	7	2		2	4		2
Asteraceae undiff.		7	7	2	3	6	4	1	2
Cyperaceae	2	4	4	5	1				5
Rubiaceae	5	4		1		3			1
Hordeum type	2		2	2	1	2			1
Avena/ Triticum type				1			2		
P. lanceolata						4			
Plantago spp..		4				2			1
Potentilla type						1			
Primula veris type			1						
Ranunculaceae		1				1			1
Rosa type	1								
Apiaceae			2						1
Unknown		1		6	2	4	6		3
Sphagnum	1	2	3	2	3	0	12	1	6

Table 5.1 Location A minor pollen taxa (n)

Sample	5	10	15	20	25	30	35	45	50
ASM003		1							
ASM006				1					
ASM010	1								
ASM016		1							
ASM029	4	3	3	4			2	1	3
ASM035				1					
ASM036	9	1	4	2					
ASM042				4		1	1		3
ASD005				1	1			1	1
ASP001		1		2					
DII005			1	1					
MOI009	2	3							
MOI012	1		1	2					
TRI003	2								
Toruloid fragment	1			1					
Agglomerate	2		3	2					1
IC010	2		1	1	2	2			1
IC011	0	1				4	1		1
"hair"	8	5	8	17	1	4	8	15	4

Table 5.2 Location A minor NPF form types (n)

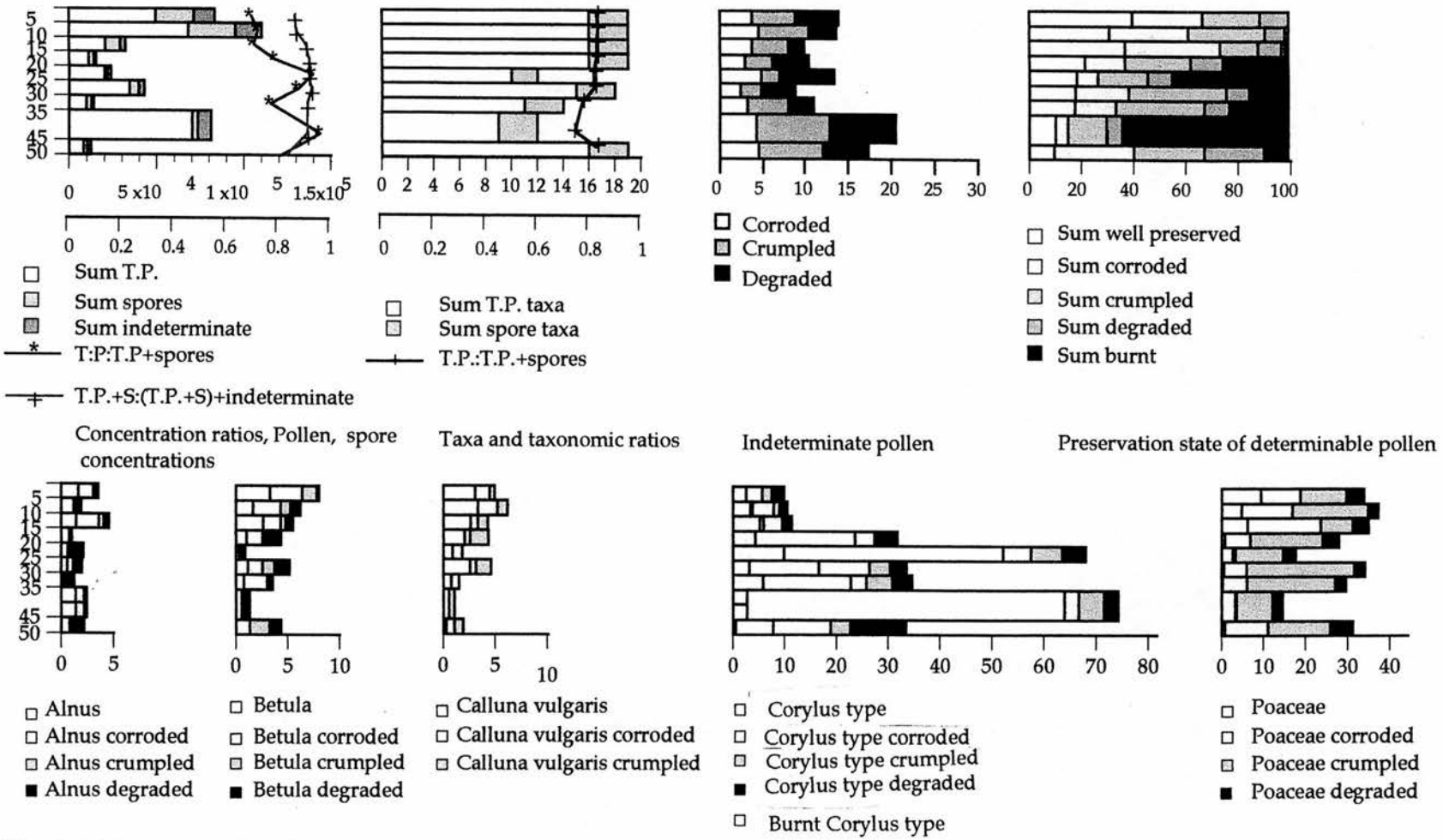


Fig. 5.13 Location A pollen preservation measures

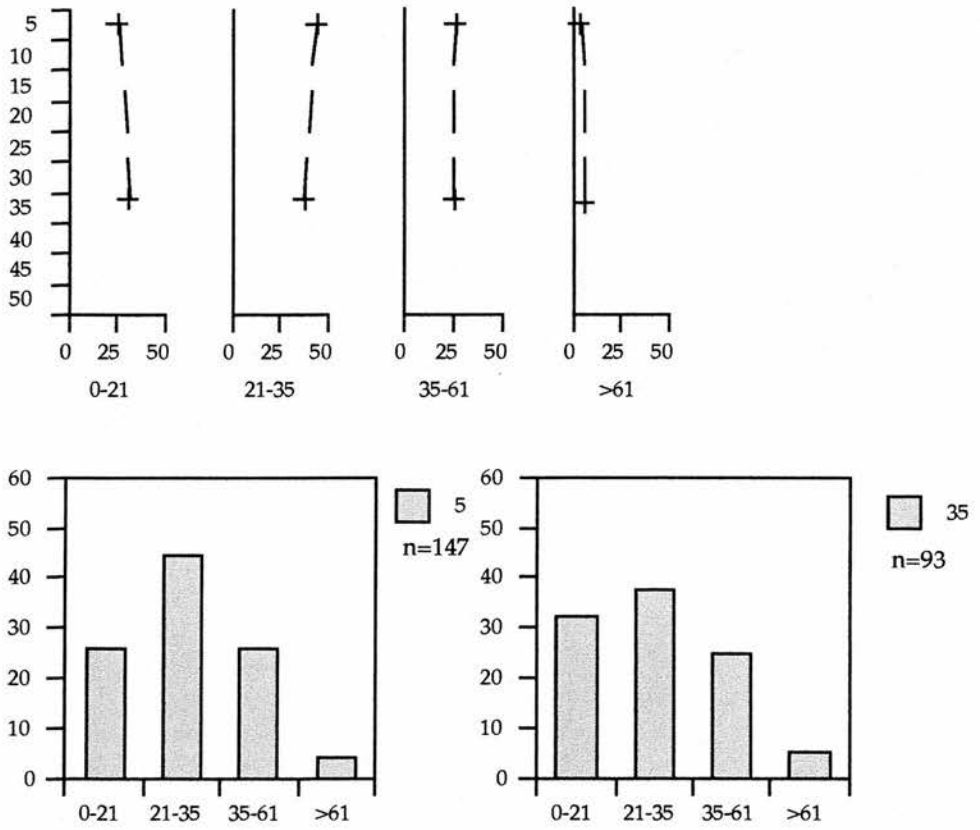


Fig 5.14 Location A fungal hyphal length (μm) frequency analysis

Location B : Sampling location and soil profile description.

This sample was collected from beneath the external ramp of the monument (Fig 5.7, Appendix 5 Fig. 14.2). Because of the stoniness of the soil samples were collected in 10 mm thick slices direct from the cleaned section adjacent to where the soil micromorphological sample had been obtained. The soil profile at this location comprised a single brown organo-mineral horizon(not illustrated) typical of a heavily bioturbated freely draining podzols, with no evidence of stratigraphy (Simpson and Davidson 1997). No radiocarbon dates were obtained from this deposit.

Location B: Local Palynofacies assemblage zones. Pollen preservation and fungal hyphal analysis.

Because of the limited number of samples analyzed at this location (4) and the absence of distinctive changes between samples, the samples are considered as a single LPfAZ.

LPfAZ SWPG B1 (0-50 mm)

Pollen dominates the discrete microfossil assemblage assemblage with frequencies between 75-80 % of the total. The samples show a series of trends within the TLP and NPF spectra from the base to the surface samples. At the base the sequence is dominated by Poaceae pollen (*c.*40%) with *Corylus* type pollen also important (29.5%) (Fig 5.15), levels of indeterminate pollen are high, and pollen concentrations are low (Fig. 5.16). The fungal spore assemblage is dominated by the morphologically similar types ASM006 and ASM007 (Figs. A5. 3.5, 3.6), and levels of palynodebris are very low (Fig. 5.17).

A series of transitions in several taxa occurs between 30 mm and 0 mm, which leads to increases in Poaceae and *Calluna vulgaris* and a decline in frequency of *Corylus* type pollen. There are also changes in the NPF assemblage with an increase in fungal spore type ASM020 (Figs. A5. 3.11) and decline in fungal spore types ASM007 and MOI016 (Fig. A5. 6.1) (Table 5.4), also increases in charcoal, hyphal fragments and plant debris occur. A number of unpigmented hyphal fragments were identified at this sampling location, in addition to pigmented hyphal fragments. Present in most samples were individual grains of *Hordeum* type, and *Plantago lanceolata* (Table 5.3). In sample 0-10 mm there is an increase in the amount of *Pinus* pollen to

c. 2% of TLP.

Pollen preservation

The sequence from Location B is similar to other podzol sequences in that there is a decline in absolute pollen frequency down profile. This pattern is accentuated by the high pollen concentration count in sample 0-10 mm (Fig. 5.18). Similar variations in podzol profile concentrations have been discussed by Dimbleby (1961, 1962, 1985) and Keith-Lucas (1986). Better measures of pollen reliability in this case are those provided by the ratio of T.P to T.P.+S and the measures of preservation classes (Fig 5. 18); which show a general decline in the number of species down profile and a decline in the amount of well preserved pollen.

The top two samples display relatively good preservation, indeterminate pollen values are low, and well preserved pollen is in excess of 60%, though this drops to under 50% by sample 20-30 mm. The bulk of the recognizable pollen is characterized by crumpling, with degradation and corrosion being of lesser importance. These traits have changed by the base of the sequence. Here under 10% of the pollen is well preserved and corrosion is apparent on over 50% of the recognizable grains, and there is a significant decrease in the number of crumpled grains. This would indicate that the sample from 40-50 mm is less well preserved than those above. Thus by almost all measures the top of the profile is relatively well preserved as has been remarked already. The sample from 40-50 mm appears to have undergone more degradation which appears to have biased this sample through the selective removal and destruction of pollen, resulting in lower pollen concentrations and numbers of taxa.

Fungal hyphal length frequency analysis

Two samples were examined in this study for hyphal length frequency samples 0-10 mm and 20-30 mm (Fig. 5.19). Size classes of hyphal fragments in decreasing order of magnitude are 21-35 um, 35-61 um, 0-21 um and greater than 61 um. Curiously there is a slight trend for a decrease in the two shorter classes down profile and in increase in the larger size classes. The hyphal frequency analysis at this location suggests an intermediate soil fauna within which both larger soil fauna such as earthworms and arthropods and the Oribitei were involved in hyphal comminution and pollen transportation. This accords well with the soil micromorphological analysis which has shown that this soil is bioturbated. This may be contrasted with the position at Location A which has a relatively undisturbed soil pollen profile.

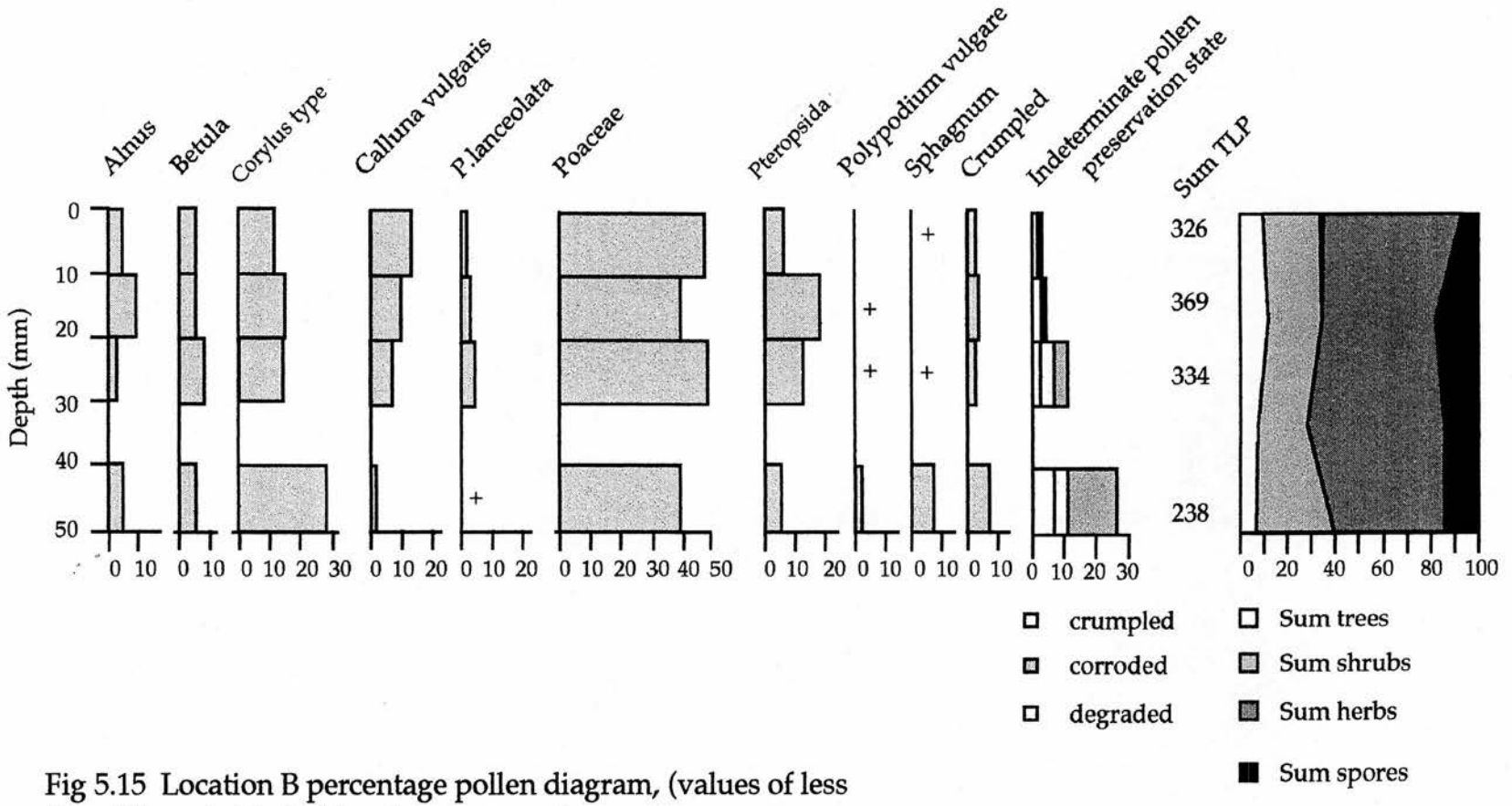


Fig 5.15 Location B percentage pollen diagram, (values of less than 2% are indicated by +)

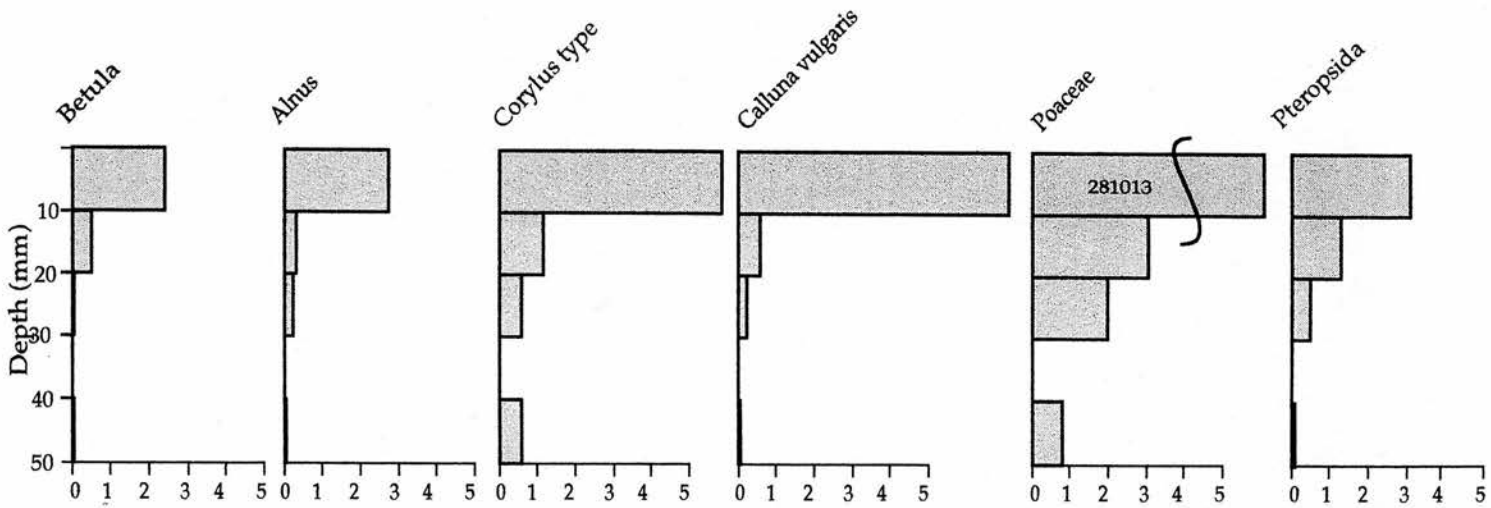


Fig 5.16 Location B pollen concentration diagram ($x10^4$(grains/cm^3)

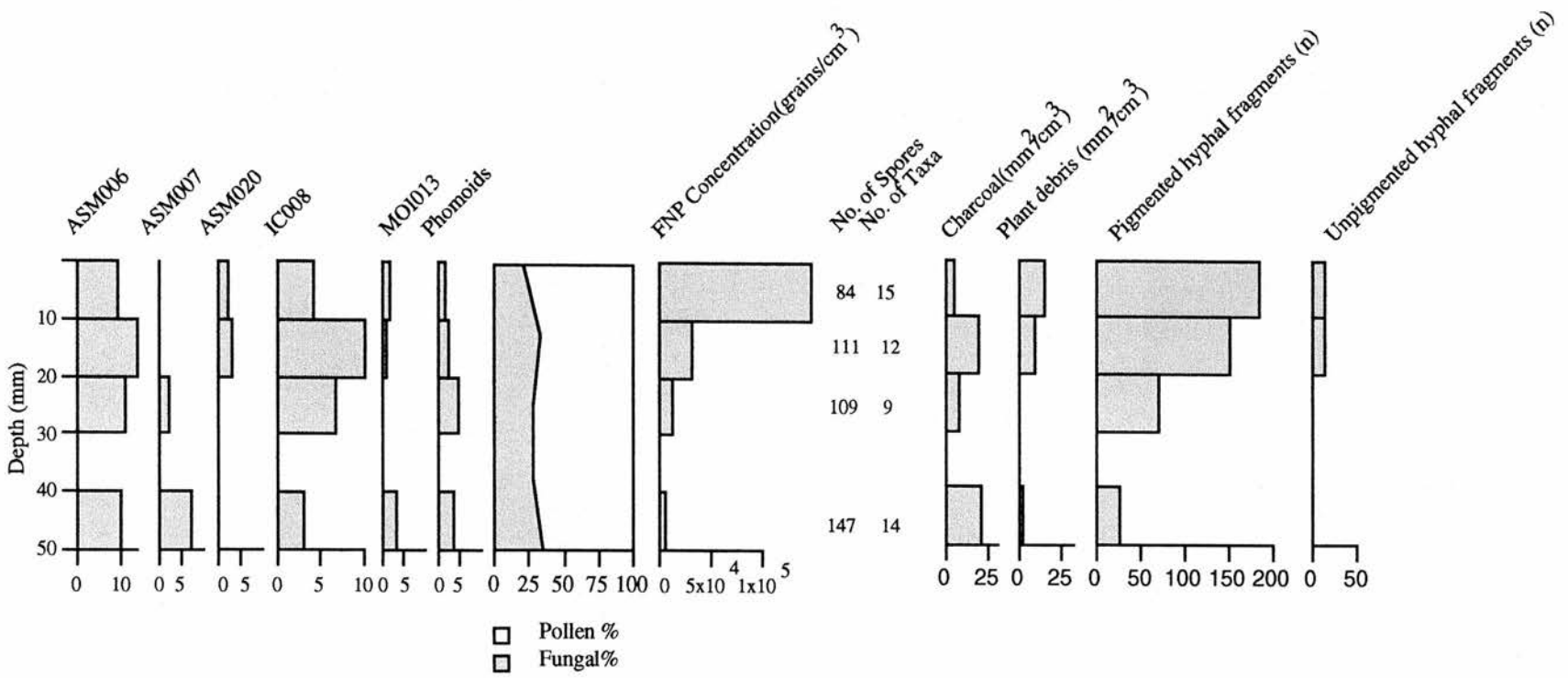


Fig. 5.17 Location B percentage NPF diagram Σ_{fun}=TLP+NPF

Sample/depth	10	20	30	50
Pinus	7	2		
Quercus	2	3		
Ulmus	1			
Salix	3			1
Ericales	4	2	4	1
Alchemilla type		1		1
Artemisia		1		1
Caryophyllaceae	2		2	
Asteraceae lactucoideae	3	6	5	
Asteraceae undiff.	9	4	4	4
Cyperaceae		1	2	
Rubiaceae	3		1	1
Hordeum type	1	1		1
Brassicaceae			1	
Plantago lanceolata	5	6	9	
Plantago major type	1	2	2	
Plantago spp.	1	3	1	2
Papaver rhoeas type	1			
Ranunculaceae	2		2	
Succisa pratensis	2	2		1
Lamiaceae	2	1		
Apiaceae	1	1	1	
Unknown	1	1		1
Valeriana officinalis				3
Polypodium vulgare	4	3	4	7
Sphagnum	1	1	4	6
Selaginella selaginoides			1	

Table 5.3 Location B minor pollen taxa (n)

DEPTH	10	20	40	50
ASI003	1			
ASI010	1			
ASM029				1
ASI039	2	3		6
ASM004			2	1
ASM037		2		
ASM038				7
ASD005		1		
IC009		3	1	6
DII007		1		
MOI015	1			
MOI017	1			
MOI018				2
MOI019				1
AGGREGATE		2	1	
BROKEN/CORROD			10	1
TORULOID	1			2
HAIR	3	2	1	

Table 5.4 Location B minor NPF types (n)

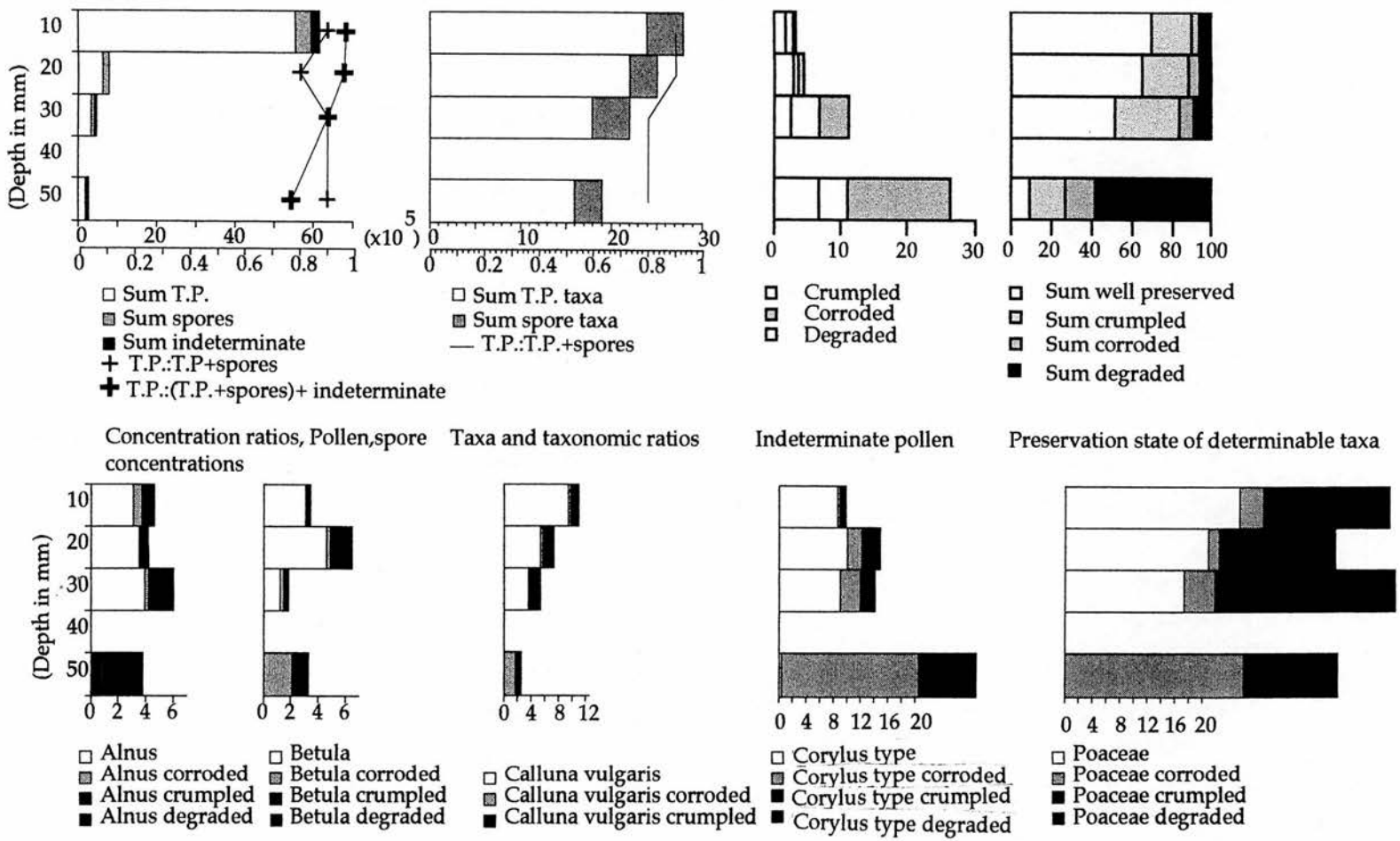


Fig 5.18 Location B pollen preservation measures

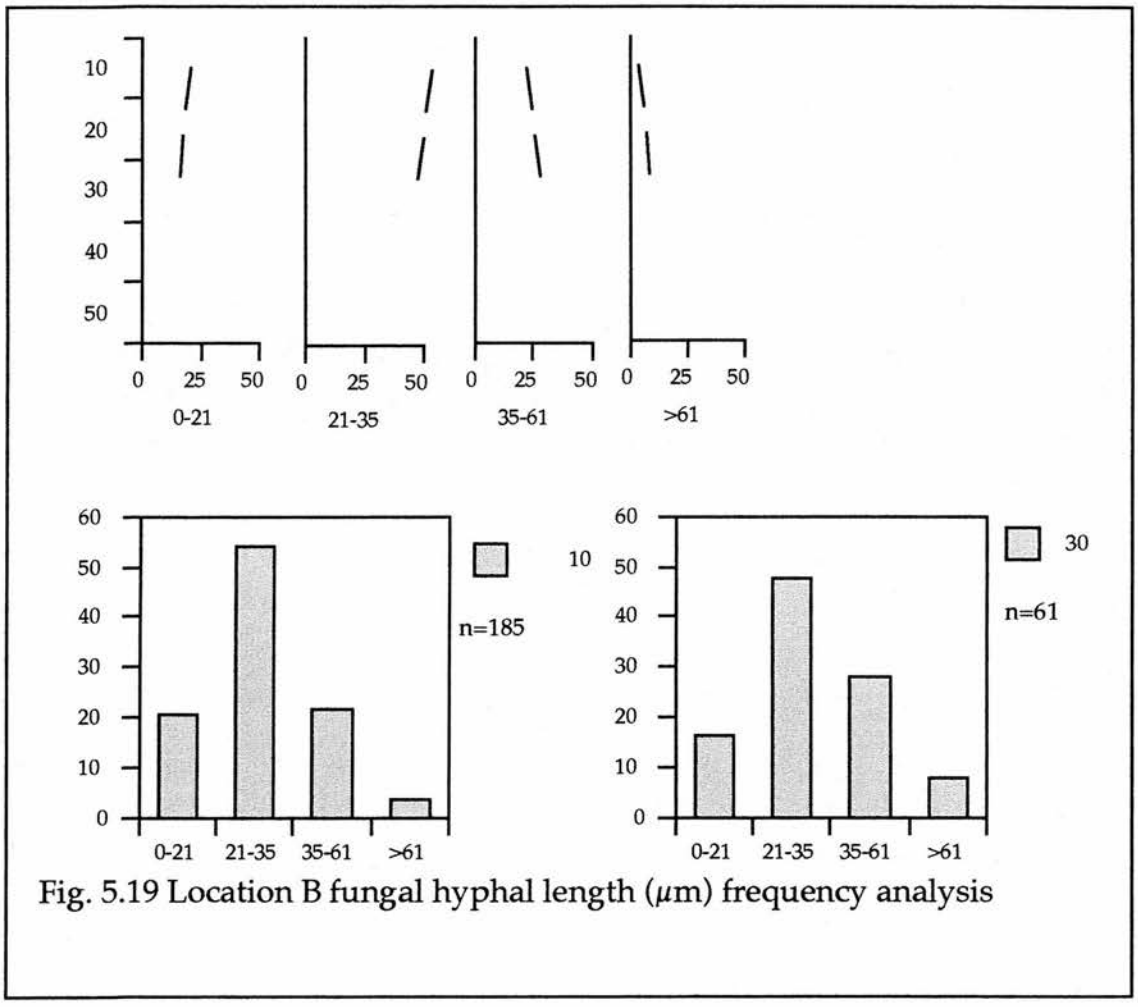


Fig. 5.19 Location B fungal hyphal length (μm) frequency analysis

Balnuaran of Clava central (Clava type ring cairn)

Site description

Balnuaran of Clava central, is a large *c.* 20 m diam ring cairn of Clava type, with a outer large diameter stone circle (*c.* 30m in diam) Fig 5.20. Appendix 5 Figs 13.2, 15.1) (Henshall 1963). This cairn is unique in possessing three 'rays' of rubble that run out from beneath the cairn to the surrounding stone circle. The central chamber and a small area outside the cairn site was excavated by Piggott (1956). Piggott found evidence for cremation in the central area and for burning outside of the cairn. The excavations of the Reading team concentrated on the ray on the south side of the cairn in an attempt to see if it originated underneath the cairn or was a later addition. This involved excavating a section through the body of the cairn out to the surrounding stone circle. In addition a wide area between the stone circle and cairn was examined to see if there was any activity in this area (Fig. 5.20). The largest number of stone tools found in all the excavations was at this location. Also located between the cairn and stone circle was a later first millennium AD cremation. The excavation suggested that the cairn/ ramp, ray and stone circle were constructed simultaneously. To provide environmental information two locations were sampled for soil palynofacies analysis from areas also sampled for soil micromorphological analysis.

Location C: Sampling location and soil profile description

This sample was collected as a *c.* 50 mm thick soil block from beneath the external ramp of the monument further sub-sampling took place in the laboratory as described in Chapter 3. As with the other samples a sample was taken for soil micromorphological analysis from an adjacent location. No radiocarbon dates were obtained from the external ramp of the monument.

The soil profile at this location is similar to that from beneath the external platform at Location B, and consists of a single horizon of a brown organo-mineral soil (not illustrated) consistent with heavy biological reworking of a podzol (Simpson and Davidson 1997 p.5). However, there is some slight evidence for admixture of material to this deposit (Simpson and Davidson 1997). No radiocarbon dates were obtained from this deposit.

Location C Local Palynofacies assemblage zones. Pollen preservation and fungal hyphal analysis.

In the samples at this location there is a slight argument for separating discussion of sample 0-10 mm from the remaining samples 10-40 mm, on the basis of changes in both pollen taxa and NPF types and the palynodebris content.

LPfAZ CRC C1 (Samples 10-50 mm)

These samples are characterized by high frequencies of *Corylus* type and Poaceae pollen, levels of *Calluna vulgaris* pollen at or under 10% and relatively high levels of *Primula veris* type pollen (Fig 5.21). Indeterminate pollen is high in these samples, between 10-20 %. The fungal spore assemblage is dominated by a number of morphologically similar monoseptate fungal spore types (MOI013, 017, 018) and diseptate fungal spore types (DII006, 007) (Figs. A5. 5.13, 6.2, 6.3, 6.9, 6.10), (Fig. 5.23). Overall, the NPF assemblage represents over half of the microfossils identified at this sampling location. Levels of plant debris are low, whilst those of hyphal fragments appear to fluctuate considerably, both pigmented and unpigmented hyphal fragments are present in this zone.

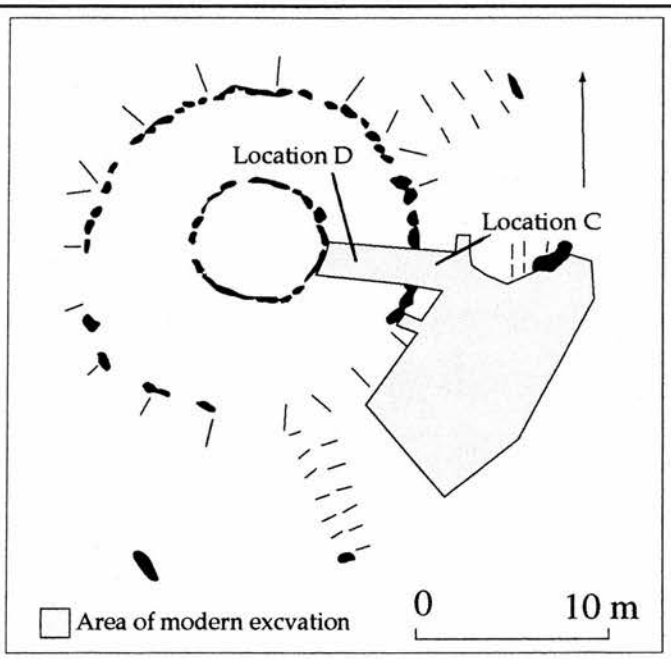


Fig. 5.20 Position of excavated areas and soil palynofacies sampling locations at Balnuaran of Clava central

LPfAZ CRC C2 (Sample 0-10 mm)

The main reason for separating deliminating this zone is the increase in frequency in both percentage and concentration of *Calluna vulgaris* (Fig.5. 21, 5. 22). Sample 0-10 mm in addition has a increased frequency of plant debris and charcoal. There are several changes to the NPF assemblage in this sample principally, declines in fungal spore types ASI003, DII006, DII007 and MOI013 and MOI018, (Figs. A5.1.1, 5.13, 6.3, 6.9, 6.10).

Pollen preservation

Concentrations and pollen ratios are consistently high for the top 40 mm of this sequence (Fig 5. 24). There is a sudden drop in pollen concentration at 40-50 mm, but this does not appear to affect the number of taxa recovered. Similarly the proportion of well preserved pollen down profile is relatively constant at around 28% dropping to 22% at 40-50 mm. There is a gradual decline in the amount of crumpled pollen down profile, possibly related to the drop in Poaceae pollen, whilst there is a rise in the proportion of both degraded and indeterminate pollen down profile.

Hyphal frequency analysis

Two samples were analyzed for hyphal frequency, 0-10 mm and 40-50 mm (Fig 5.25). In sample 0-10 mm fragments of length 0-21 and 21-35 μm dominate , with fragments of 35-61 μm >61, μm length less important. By sample 40-50 mm there is an increase in longer fragments and a decline in shorter fragments 0-21 μm. The topmost sample (0-10 mm) indicates the importance of Oribitids in the comminution of hyphal fragments whilst the basal sample is dominated by longer fragments indicating the activity of larger soil fauna. The hyphal frequency analysis suggests that this soil profile has been bioturbated a conclusion which concurs with the soil micromorphological analysis at this location.

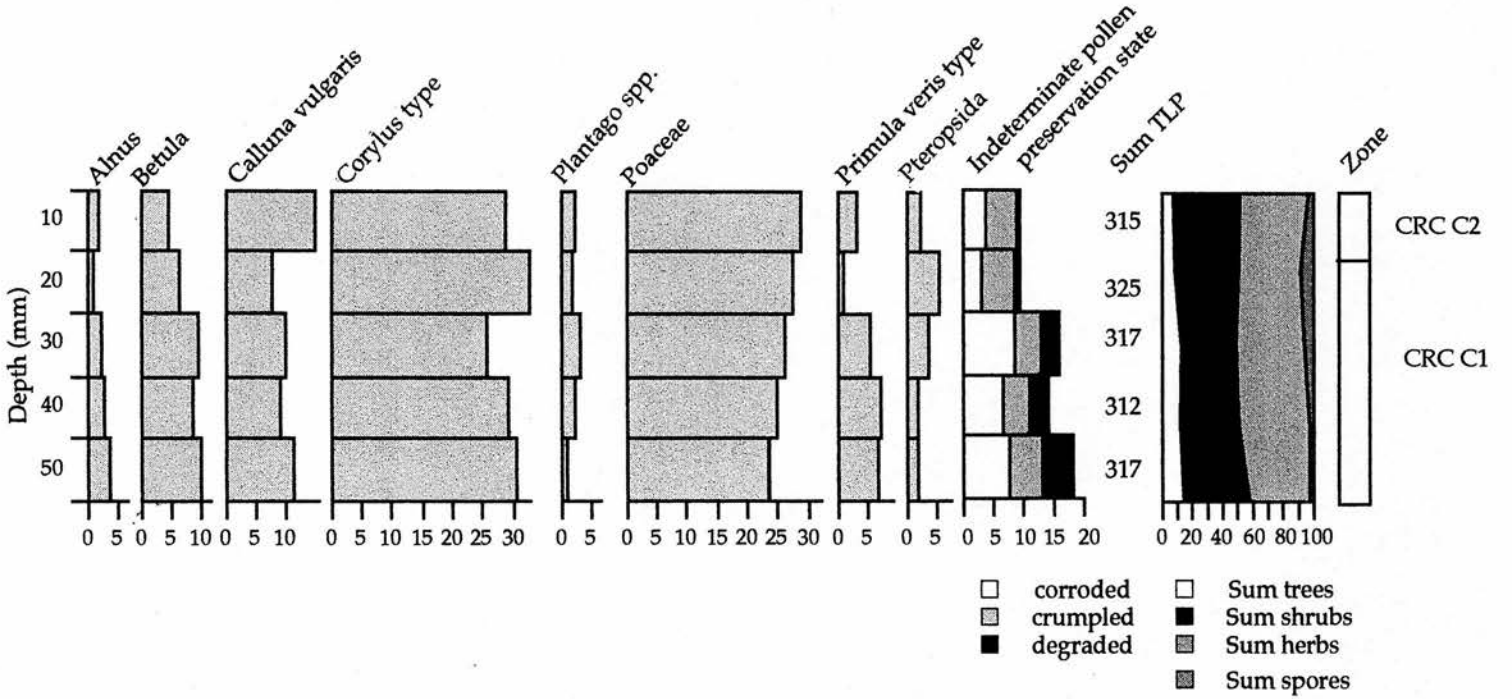


Fig 5.21 Location C percentage pollen diagram (values of less than 2% are indicated by +)

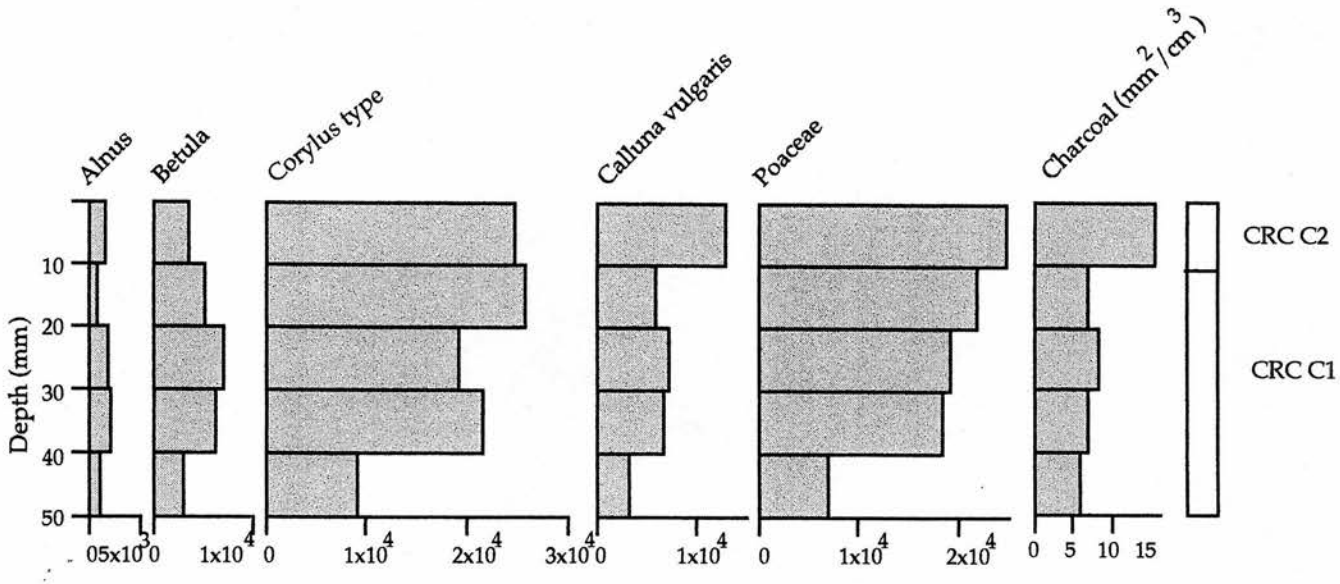


Fig 5.22 Location C pollen concentration diagram (grains/cm^3)

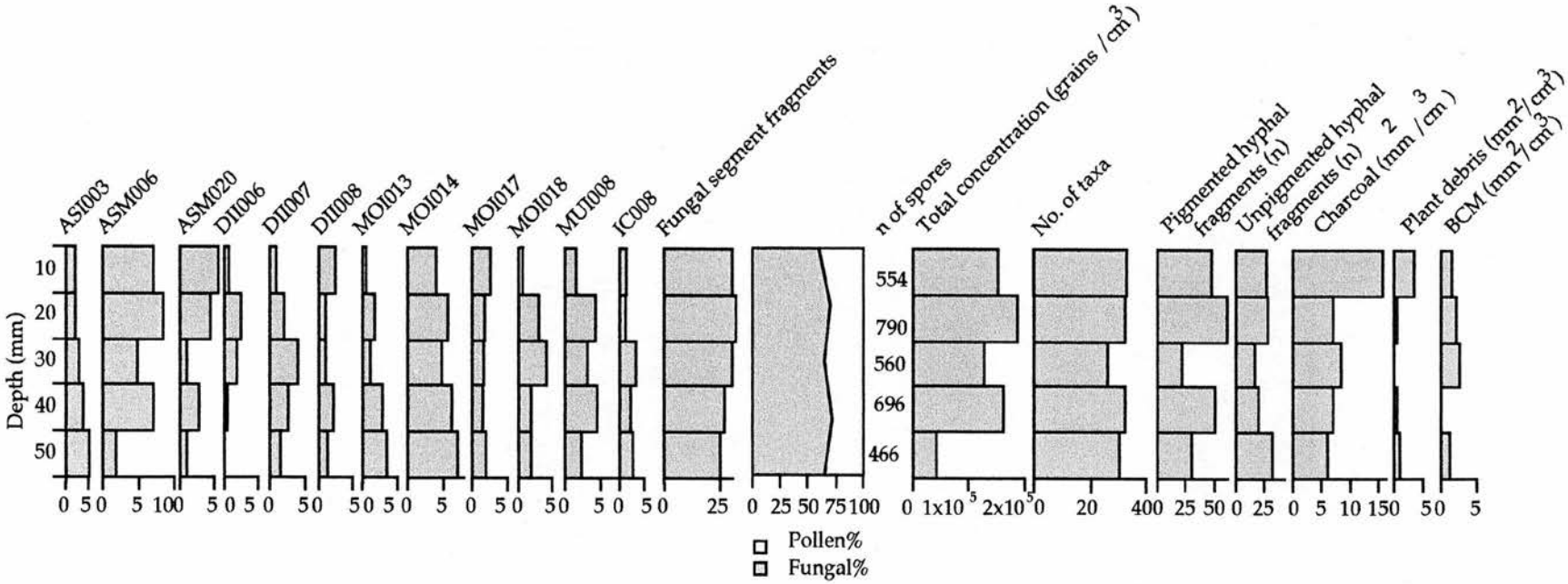


Fig. 5.23 Location C, percentage NPF diagram (Σ_{fun}=TLP+NPF)

Taxa/depth	10	20	30	40	50
Pinus	1	1	0	1	1
Quercus	1	1	1	1	1
Salix	0	1	0	0	2
Ericales	4	4	3	3	2
Artemisia		1			
Caryophyllaceae	1	2		2	1
Chrysosplenium			2		2
Asteraceae lactucoideae	5	4	3	4	3
Asteraceae undiff.	2	5	3	2	1
Cyperaceae	3	1	2	5	2
Rubiaceae	11	11	11	13	9
Plantago lanceolata	2		1	1	
Plantago spp..	7	6	11	8	4
Ranunculaceae	2	2		2	3
Rosaceae type			1		
Rumex acetosa type	1				
Succisa pratensis	1	1	4		2
Apiaceae				1	
Urtica urens type		3			
Valeriana officinalis			1	1	
Unknown	4	3	3	5	4
Pteridium aquilinum	2	3			
Polypodium vulgare	2	7	5	3	1
Sphagnum			3		2

Table 5.5 Location C minor pollen taxa (n)

Sample	10	20	30	40	50
ASI010	0	1	1	0	0
ASI026	1	0	0	0	0
ASI039	2	1	1	4	2
ASI040	1	0	0	1	2
ASI041	11	1	8	4	5
ASM001	0	0	0	1	0
ASM018	2	0	0	0	0
ASM037	0	2	0	0	2
ASM038	0	0	0	1	0
ASM041	0	1	0	0	0
DII005	15	4	0	0	2
MOI006	0	0	0	6	7
MOI009	5	3	3	5	4
MOI011	1	0	0	0	0
MOI015	0	0	0	14	20
MOI016	3	2	3	1	2
MOI019	1	0	0	8	8
MOI012	1	0	0	0	0
ASM005	0	0	0	1	0
ASI040	2	2	0	2	0
BROKEN/CORRODED	0	12	6	4	0
"hair"	1	4	2	0	1
IC011	5	3	0	0	4

Table 5.6 Location C minor NPF types (n)

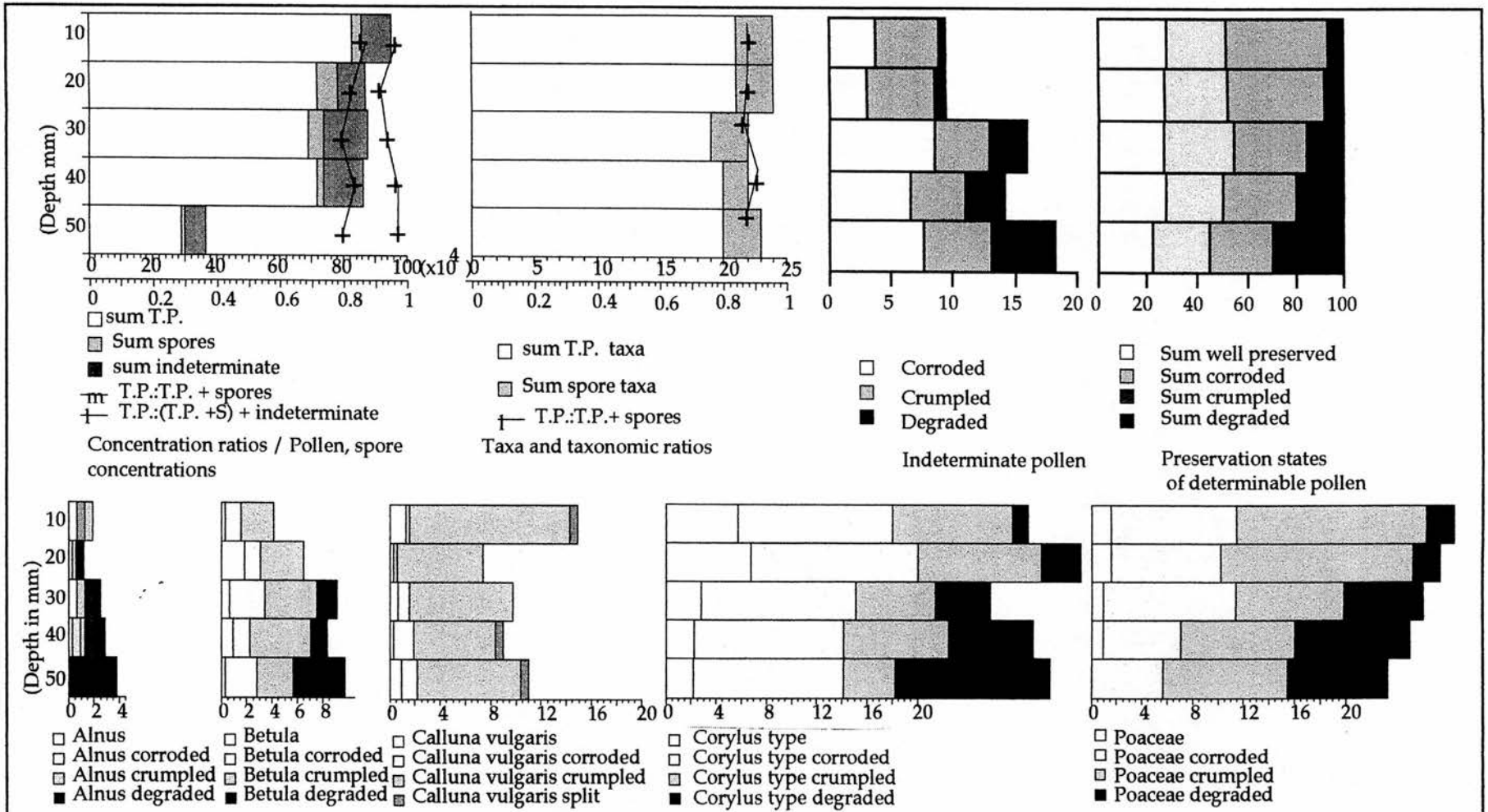


Fig. 5.24 Location C pollen preservation measures

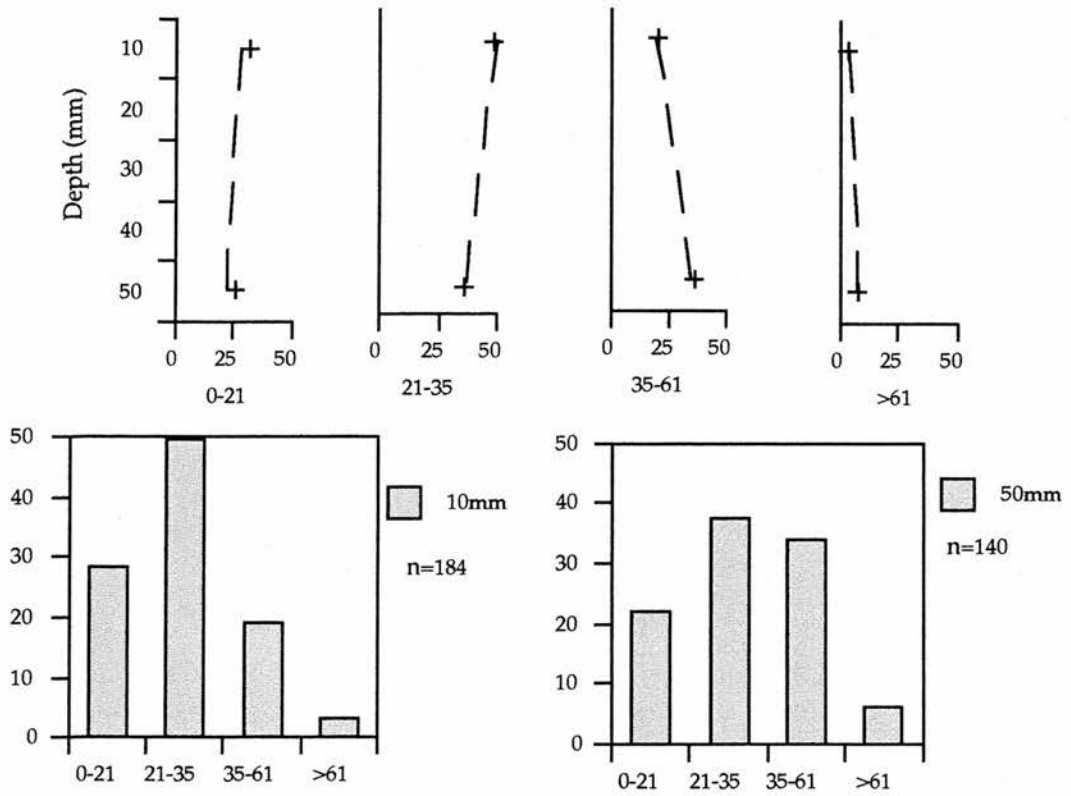


Fig. 5.25 Location C fungal hyphal length (μm) frequency analysis

Location D: Sampling location and soil profile description

Conditions for sampling within the cairn of Clava central were problematic due to the presence of large unstable boulders. Despite this it was possible to obtain two congruent samples for both soil palynofacies and soil micromorphological analysis. These were obtained by Kubiena tins from beneath a large boulder, sub-sampling took place as described in Chapter 3.

The soil profile at this point was of a brown organo-mineral horizon that had been bioturbated (not illustrated) (Simpson and Davidson 1997), similar to that at Location C. At Location D however Simpson and Davidson (1997) suggest that biological reworking was less than that at Location C and there was evidence for clearance of the area by burning prior to the construction of the ring cairn.

Radiocarbon dating

Three radiocarbon dates were obtained from beneath the body of the cairn. Unlike those from Location A and E they represent a wide spectrum of dates, either as a result of residual charcoal, the admixture of charcoal after the monument was constructed, or a later date for the construction of the monument.

AA-21255 6410 ± 80 uncal BP 2σ 5490-5230 cal BC

AA-21256 3605 ± 75 uncal BP 2σ 2194–1750 cal BC

AA-21257 2990 ± 70 uncal BP 2σ 1420–1010 cal BC

Despite coming from sealed locations beneath the monument three dates have produced evidence for three different widely spaced periods. As primary dating evidence these dates leave a lot to be desired and highlight the difficulty of using small fragments of charcoal from a rubble built structure. Other dates are also available from the exterior of the monument but they appear to relate other periods of activity at the site (Appendix 9). The dating evidence from this cairn will be considered further below.

Location D Local Palynofacies assemblage zones. Pollen preservation and fungal hyphal analysis

This sequence is divided into three zones on the basis of changes in the pollen and NPF assemblages and in the amounts of the palynodebris assemblage.

LPfAZ CRC D1 (100-60 mm)

This zone is principally defined by the rise in fungal hyphae frequency, brown carbonized material, and a increase in plant debris and charcoal at 60 mm (Fig 5.28). Other characteristics include the fungal spore types DII005 (Fig. A5. 6.8.), agglomerate type and by low frequencies of *incertae cedis* types IC008 and IC009 (Figs. A5.8.1, 8.2), (Table 5.8). The zone is further defined by frequencies of Poaceae pollen at *c.* 20%, and *Betula* pollen at *c.* 10% (Fig. 5. 26). The overall microfossil assemblage is dominated by pollen microfossils with a maximum of 90% Two grains of *Hedera helix* pollen were also identified in this zone (Table 5.7).

LPfAZ CRC D2 (60-25 mm)

The zone is defined by low levels of fungal hyphae and brown carbonized material and low levels of charcoal. Other important elements of this zone are the absence of fungal spore type DII005, and a decline in agglomerate type. In the pollen spectra an increase in the frequency and concentration of Poaceae pollen (Figs. 5.26, 5.27) from the previous zone, help to define this zone. Also within the zone there are a number of cereal type pollen grains (Table 5.7) and a increase in the amount of *Plantago lanceolata* occurs. The discrete microfossil assemblage again is dominated by pollen microfossils with frequencies of *c.* 60-70%.

LPfAZ CRC D3 (25-0 mm)

Within this LPfAZ an increase in *Calluna vulgaris* pollen occurs after 25 mm to *c.* 18% of TLP and there is a reciprocal decline in the level of *Corylus* type pollen but tree pollen *(Betula* and *Alnus)* and Poaceae pollen appear to be unaffected. This zone is also marked by an increase in broken and corroded spores and by increases in the fungal spores Phomoid type, ASI039, and ASM001 type, (Figs. A5.8.6, 2.1, 3.1). Increases also occur in the numbers of fungal hyphae and in the amount of charcoal and plant debris. The topmost sample (0-5 mm), is distinct from the other samples in this zone with increases in the frequency of Poaceae, and *Pinus*, pollen, and a decline in *Calluna vulgaris, Betula* and *Alnus* pollen frequencies. Significant changes occur in the palynodebris spectra in sample 0-5 mm with increases in the amount of plant debris, and charcoal. Also, increases in fungal spore types ASM004 and type ASM029, (Figs. A5. 3.3, 4.1) occur in sample 0-5 mm. The

microfossil assemblage throughout LPfAZ CRC D3 is dominated by pollen at *c.* 70 % except in sample 0-5 mm where NPF microfossils account for nearly 50% of the microfossil assemblage.

Pollen preservation

From the concentration and the pollen taxa measures it may be inferred that the pollen from the sequence is well preserved and it is unlikely that there has been an appreciable loss in pollen numbers or taxa (Fig 5.29). The top 35 mm of the sequence has better pollen preservation than the lower samples. On the basis of the recovered pollen assemblages there appear to be good reasons for thinking that this sequence is less mixed than the other assemblages examined (see below). Changes in pollen percentage values are abrupt as at sample 55-60 mm and 25-35 mm, as are changes in the concentration values of the major taxa. Overall pollen preservation is excellent with large numbers of identifiable taxa.

Hyphal frequency analysis

Three samples were analyzed for hyphal frequency analysis (Fig. 5.30). The samples analyzed were dominated by shorter hyphal fragments. In particular samples 5-10 mm and 90-100 mm. The hyphal frequency data suggests that the dominant mode of hyphal comminution was by Oribitei. The low values for larger hyphal classes suggests that Lumbricid earthworms and the larger arthropods were not particularly active in this soil. This suggests that whilst some mixing of the soil pollen has occurred the profile is not as bioturbated as the sequence at Location C or the soil micromorphological analysis suggests. Sample 45- 50 mm is anomalous in that short hyphal fragments 0-21μm decline from 40% to *c.* 20% and there is a corresponding increase in all other types. This suggests that the central section has undergone some sort of bioturbation. However, the sample size is small and may not, therefore, be reliable. The soil micromorphology from this cairn suggests different degrees of bioturbation within the cairn, some areas being heavily bioturbated and others less so.

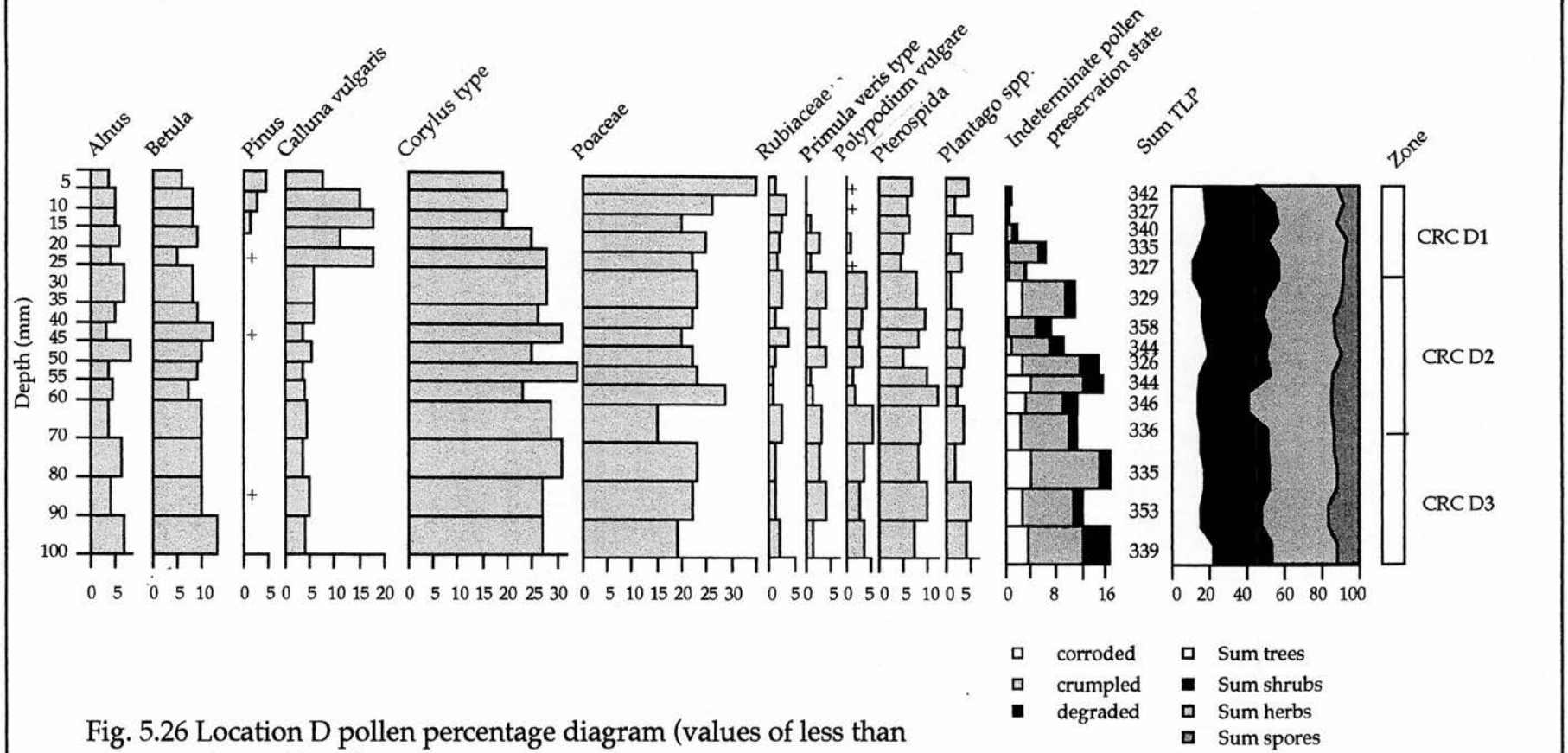


Fig. 5.26 Location D pollen percentage diagram (values of less than 2% are indicated by +)

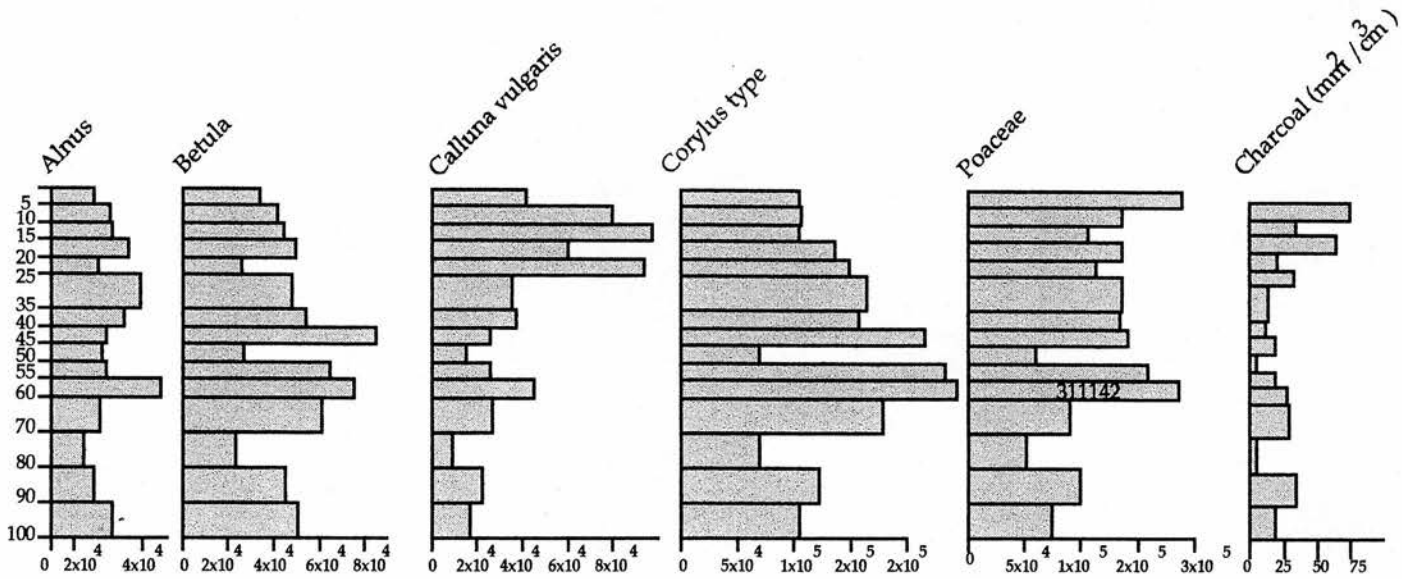


Fig. 5.27 Location D pollen concentration diagram (grains/ cm^3)

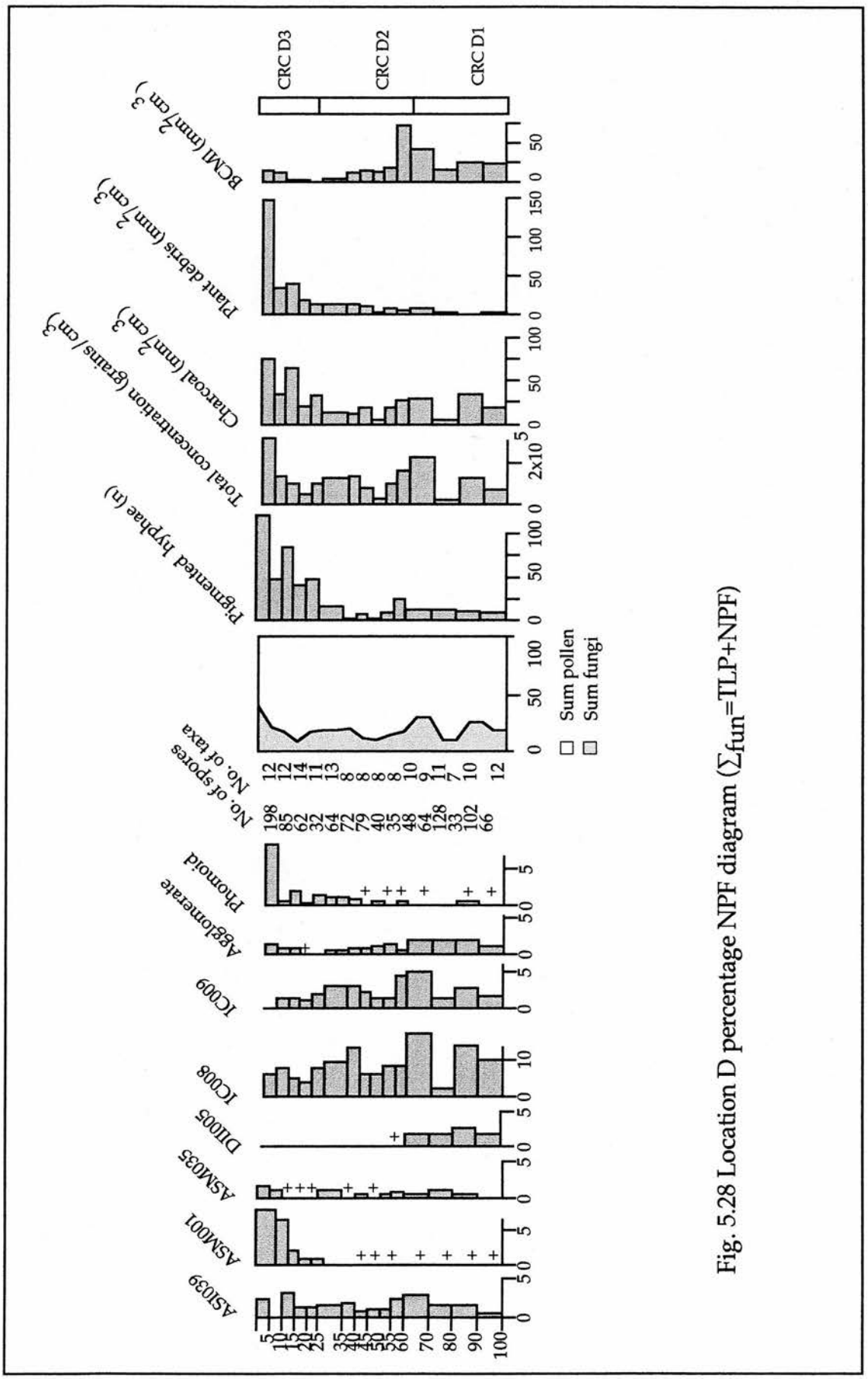


Fig. 5.28 Location D percentage NPF diagram ($\sum_{fun}$=TLP+NPF)

	5	10	15	20	25	35	40	45	50	55	60	70	80	90	100
Pinus	2	11	8	3	2			2		2	3			1	
Quercus	3	3	5		2	1	2	4	2			2	1		
Tilia		1													
Ulmus	1				1										
Empetrum		2													
Ericales	4	2	6	2	1	2	2	1	1	3	2	8	3	3	2
Salix	3	2	4		3		6	3	4	6	3	4	2	3	4
Hedera helix													1		1
Alchemilla type			1		1		1	1					1		
Artemisia							1				1			1	
Chrysosplenium	1	1			1										
Caryophyllaceae		1	1		2			3		3	2	4	1	1	
Cannabis/Humulus type		1													
Centaurea scabiosa type								1		2					
Centaurea cyanus		1													
Avena/ Triticum type			1												
Hordeum type	1	2	2	6	4	2		2	5		1		1		1
Asteraceae lactucoideae	5	1	7	2	4		4	1	3		1	2	1		2
Asteraceae undiff.	7	4	4	6	5		2	1	4	3	4	1	3	1	2
Brassicaceae							1		3						1
Cyperaceae	3	1	1				4	2	8	7	11	7	6	1	2
Rubiaceae	4	11	9	7	6		5	14	4	2	2	8	4	4	6
Hornungia type		1													1
Lotus		1													
Melampyrum					1										
Plantago lanceolata	2	2	3	6	2	1	1	1		2	1	3			2
Plantago major type	1	2			1										
Plantago spp.			3	1	4	1	11	1	14	2	4	8	7	11	6
Potentilla type	1		1												
Primula veris type	1		1	4		2	12	9	11	5	4	15	7	7	8
Primulaceae				2											
Ranunculaceae	2	1	2	1	1		3	1	4	2	2	3	1	4	1
Rosaceae				2				3	2		1				
Rumex acetosa type				1											
Scutellaria					2						1				
Succisa pratensis							2		1			1		1	
Stachys sylvatica type					3		2		1						
Stellaria holostea type			1												
Apiaceae		5	2							1		1		1	
Urtica urens type					2		3		1		1				
Vicia cracca type		1													
Pteridium aquilinum														1	
Sphagnum							3	5	1	4	1	3	5	4	1
Unknown			1	11	1		5	3	2	1	6	4	3	6	5

Table 5.7 Location D minor pollen taxa (n)

Depth	5	10	15	20	25	35	40	45	50	55	60	70	80	90	100
Agglomerate	6	3	3	1	0	2	3	2	3	4	2	8	6	7	4
ASI010	0	0	1	2	1	0	0	0	0	0	0	0	0	0	0
ASM029	18	3	1	0	2	3	0	0	0	1	0	0	0	0	1
ASI039	12	0	11	4	5	6	7	1	3	3	8	12	5	6	2
ASM004	8	4	1	1	0	4	1	1	0	2	3	3	4	2	1
ASM016	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0
ASM035	17	6	3	0	0	1	0	0	0	0	0	0	0	0	1
ASM036	6	0	2	1	3	0	0	0	1	1	0	0	0	0	0
ASD005	6	2	2	2	2	0	0	0	0	0	1	0	0	0	0
DII005	0	0	0	0	0	0	0	0	0	0	1	8	6	10	7
IC009	0	6	5	4	7	11	12	8	5	5	16	21	5	11	6
MOI012	0	0	0	0	0	0	0	0	0	0	0	0	0	6	4
Phomoid	43	2	7	1	5	4	3	0	2	1	2	1	0	2	1
Broken/corroded	10	3	1	0	5	6	0	0	0	1	0	1	0	2	1

Table 5.8 Location D minor NPF types (n)

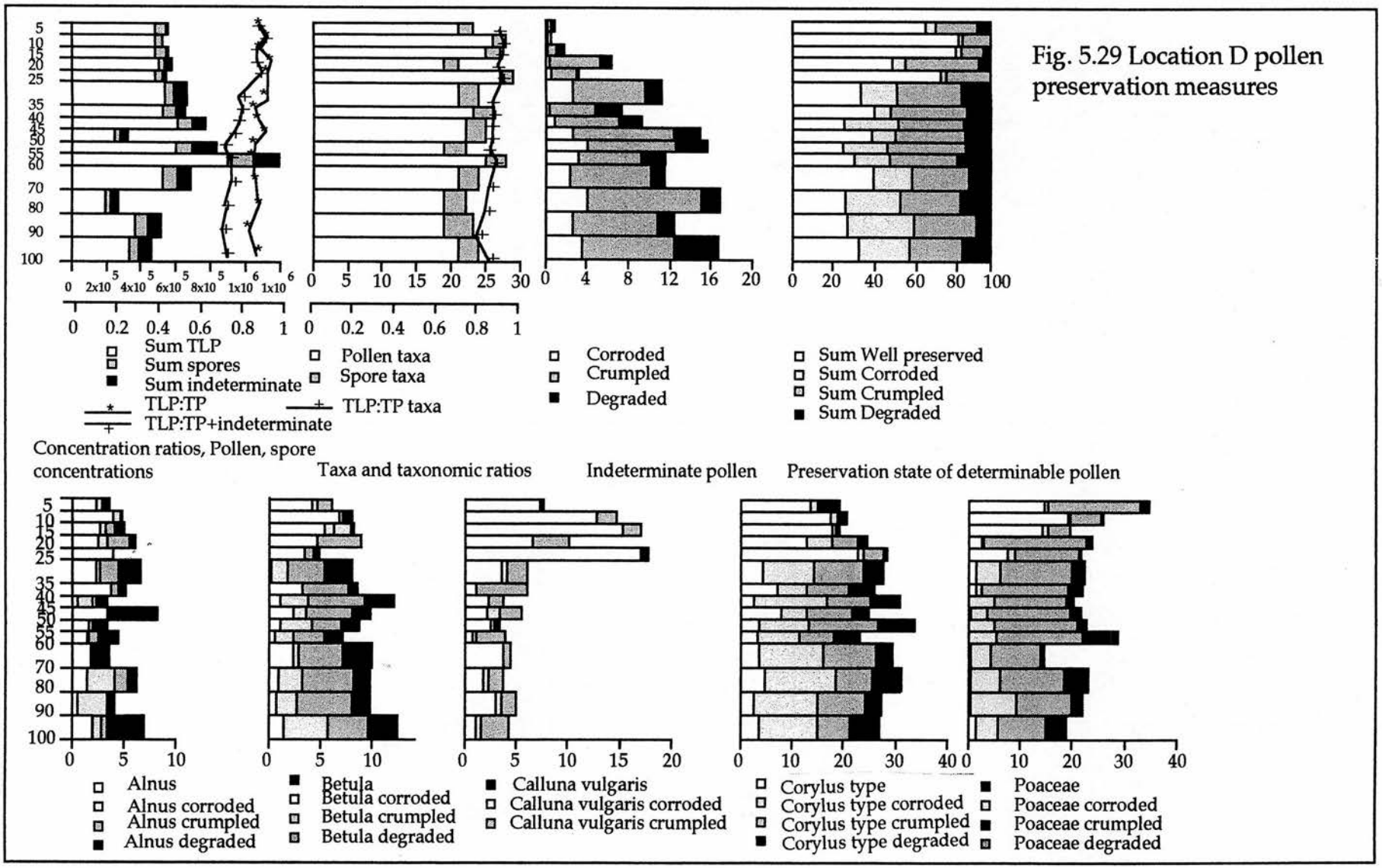


Fig. 5.29 Location D pollen preservation measures

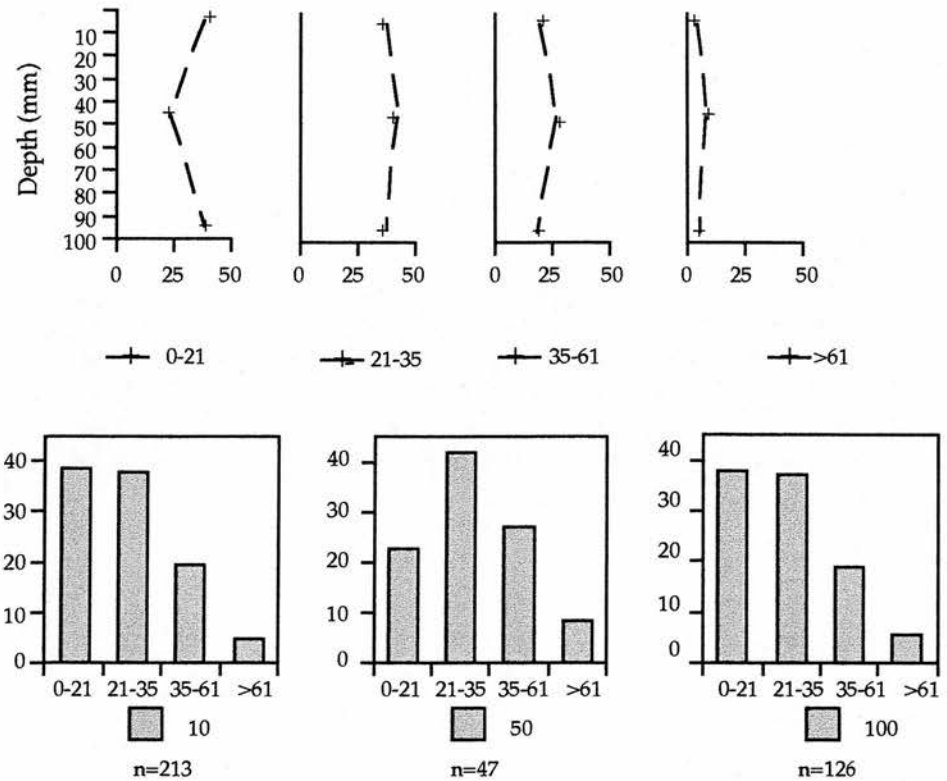


Fig. 5.30 Location D fungal hyphal length (μm) frequency analysis

Balnuaran of Clava North east (Clava type passage grave)

Site description

Architecturally this cairn is a twin of Balnuaran of Clava South-west with similar construction techniques, use of rock art, corbelling and external ramp (Bradley forthcoming). The cairn has a diameter of approximately 20m and is surrounded by a stone circle of *c.* 30-35m in diameter. As with Clava South-west there is a central chamber, with a narrow passage which is orientated to the South-west. The external ramp is wider at this site between 3-6m in width (Henshall 1963). The site was excavated by Kennedy in the 1930' s prior to the more recent excavations. The Reading team examined part of the cairn, the ramp, stone circle and entrance passage. The excavation results suggested that originally the ramp may have formed a paved area between the kerb of the cairn and the outer stone circle (Bradley forthcoming). The excavation also suggested that the ramp was in this case a later addition after the cairn was constructed. Only a single sequence was recovered from beneath the body of the cairn as no suitable sampling location beneath the ramp was available (Fig. 5.31).

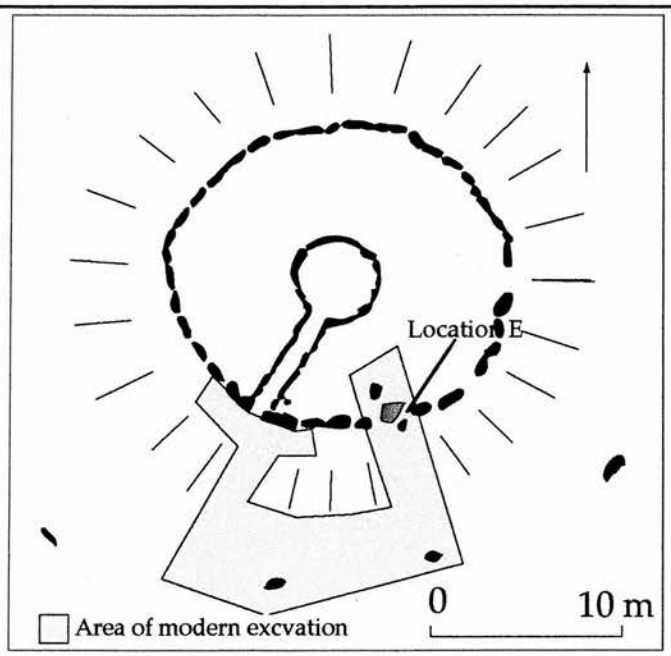


Fig. 5.31 Position of excavated areas and soil palynofacies sampling location at Balnuaran of Clava North-east passage grave.

Location E sampling location and soil description.

The deposits beneath the main body of the cairn comprised a thin *c.*30- 50 mm thick layer of bleached soil below which was a thin black layer beneath which was a further thickness of bleached soil. The soil profile therefore gave the impression of being an intact buried surface. A sample through the black layer was taken by Kubiena tin adjacent to the soil micromorphology sample and subsampled in the laboratory as described in Chapter 3.

The soil profile at this location is characterized by a upper organo-mineral dark brown A horizon underlain by a lower gray E horizon (Fig.5.32), some which appears to have been redeposited onto the upper A horizon (Simpson and Davidson 1997 p.6).

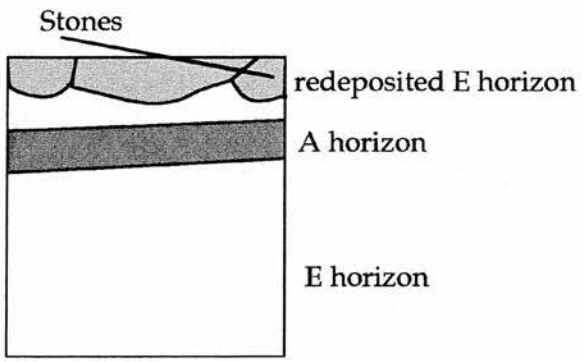


Fig. 5.32 Soil profile at Balnuaran of Clava North East (2/3 thirds life size)(After Simpson and Davidson 1997)

Radiocarbon dating

A total of five radiocarbon dates were obtained from beneath body of the North east cairn.

AA-25234 3475 ± 45 uncal BP 2σ 1920-1686 cal BC

AA-24233 3530 ± 45 uncal BP 2σ 2021-1745 cal BC

AA-24232 3595 ± 60 uncal BP 2σ 2140-1773 cal BC

AA-25231 3535 ± 45 uncal BP 2σ 2025-1747 cal BC

AA-25230 5535 ± 55 uncal BP 2σ 4500–4257 cal BC

These dates with the exception of AA-25230 form a remarkably tight group even at 2 standard deviations, suggesting that this monument was built in the years just before or just after the start of the second millenni-

um BC. It also supports the soil micromorphological interpretation that the core of the cairn has been largely undisturbed. The date from sample AA-25230 may reflect the presence of residual charcoal within the soil from earlier burning activity either natural or artificial in nature.

Three dates were also obtained from the fill of the socket of one of the entrance kerbstones.

AA-25237 2 σ 1374-1000 cal BC

AA-25236 2 σ 1520-1310 cal BC

AA-25235 2 σ 2134-1786 cal BC

The spread of dates from the socket are not internally consistent suggesting either contamination of the deposit, or later phases of activity affecting the setting of the kerbstones at the entrance. This series of dates are reminiscent of those from the ring cairn. These dates show the shortcomings in only dating small numbers of charcoal fragments from a site such as Balnuaran were the possibility of the movement of individual fragments of charcoal may be high.

Location E Local Palynofacies assemblage zones. Pollen preservation and fungal hyphal analysis.

Microfossil, particularly pollen and fungal hyphal preservation was poor in the samples from this cairn. Because of the poor preservation it was not practicable to count 300 TLP and instead three slides were counted for each level (mean count =153). In addition hyphal counts were extremely low and it was not possible to carry out hyphal frequency analysis of these samples. Three LPfAZ were recognized within this sequence of samples.

LPfAZ NE1 (90-40 mm)

This zone is defined by the high frequency of *Corylus* type pollen greater than 50% of TLP (Fig.5. 33), fungal spore types ASM039 and ASI018 (Figs. A5. 4.7, 1.4) and low levels of brown carbonized material (Fig 5.35).

LPfAZ NE2 (30-40 mm)

This zone represents the turf line identified through visual inspection of the soil profile. It is defined by an increase in the amount of charcoal fluctuations in the frequency of fungal spore types ASM035, ASM037 and

ASM038, (Fig. A5. 4.3, 4.5, 4.6). There is a decline in the level of *Corylus* type pollen and an increase in the frequency and concentration of Poaceae and *Plantago* spp.(Fig 5.34). Increases in Asteraceae lactucoideae and other minor herb taxa also occur in this zone (Table 5.9).

LPfAZ NE3 (0-30 mm)

This zone represents the upcast identified through visual inspection of the soil profile. It is defined by the absence of fungal spore types ASI018 and ASI039, (Figs. A5. 1.4, 2.1), and frequencies of Poaceae and *Corylus* type pollen similar to those of LPfAZ NE1.

Pollen preservation

Pollen counts were in general low, and this is reflected in the low concentration values and the low numbers of observed taxa (Fig. 5. 36). Within these samples frequencies of spores are low. This renders measures of preservation based on these values somewhat unhelpful, and whilst spore values may be an excellent measure of preservation (Tipping *et al.* 1994, Andersen 1988) this sequence shows that they are not always universally present in soil samples (*cf.* Dimbleby 1985). In this case better indicators of poor preservation are low pollen concentration values and high concentrations of indeterminate pollen (as much as half of the pollen count in some levels). Within both the major taxa *Corylus* type and Poaceae it would appear that corrosion has formed the dominant mode of pollen degradation. No type of deterioration dominated within the indeterminate class and this may reflect difficulties in assigning indeterminate status in cases where pollen is badly preserved. Interestingly pollen preservation measures decline away from the organic horizon, suggesting that pollen destruction is at its greatest below the organic horizon. The organic horizon has preserved the largest variety of pollen types 11 and has the largest percentage of well preserved pollen grains.

Hyphal frequency analysis

As discussed earlier the lack of significant quantities of fungal hyphae in the samples meant that meaningful analysis of these samples was not possible. the soil micromorphological analysis indicates that this sample has undergone little bioturbation.

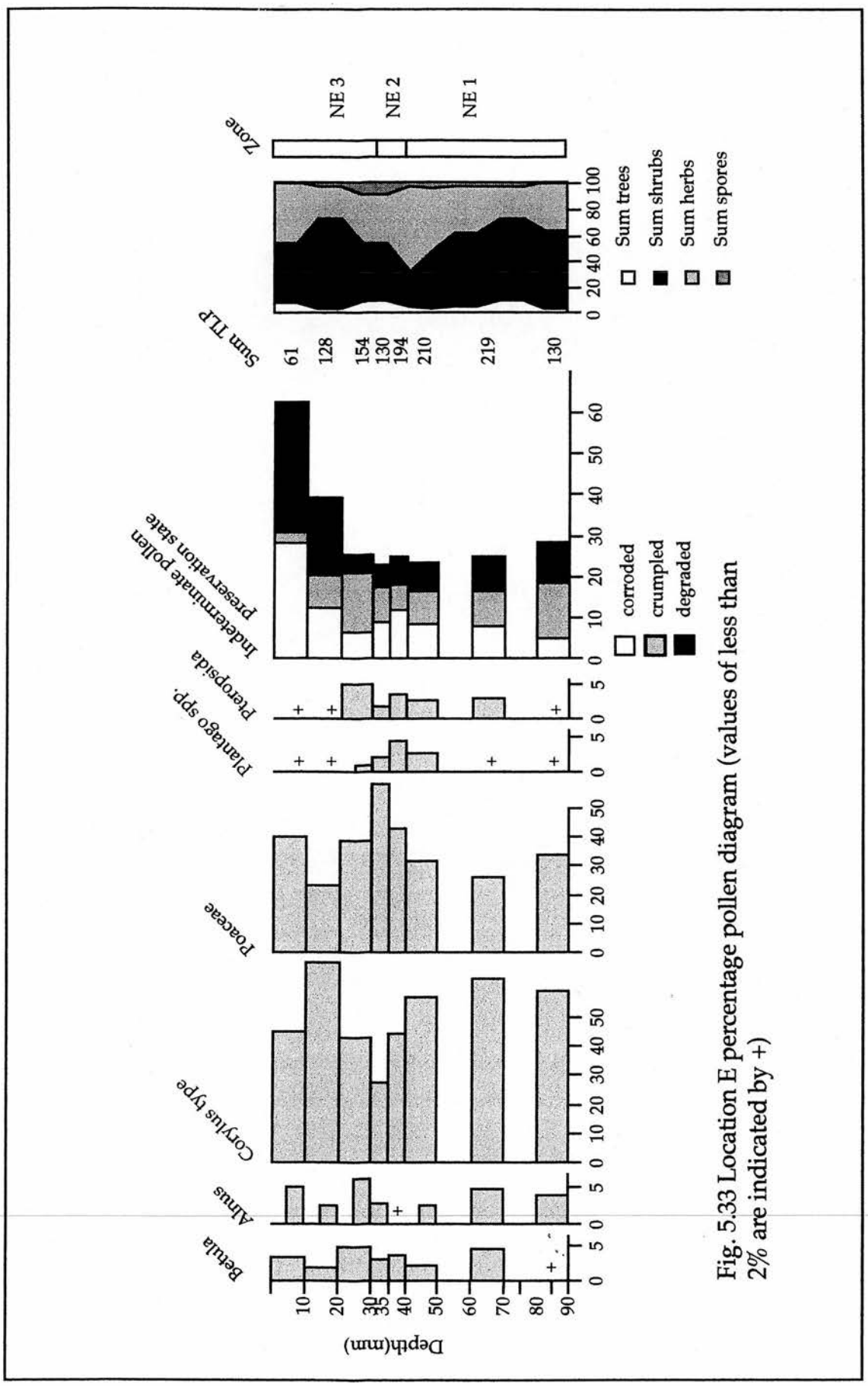


Fig. 5.33 Location E percentage pollen diagram (values of less than 2% are indicated by +)

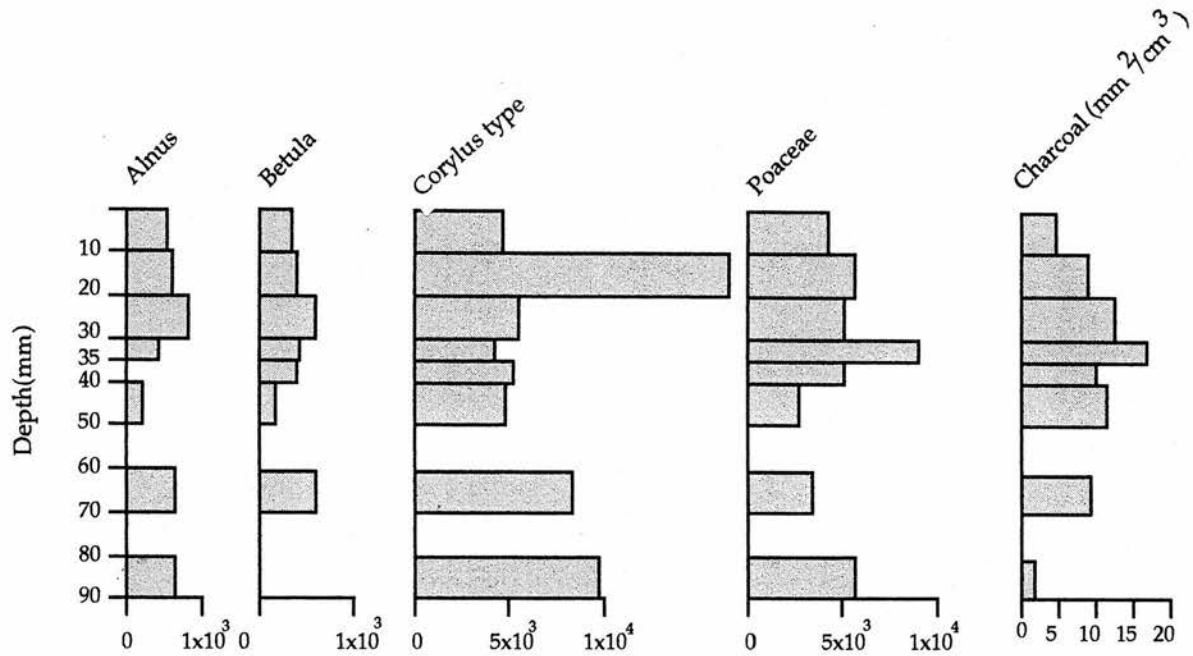


Fig 5.34 Location E pollen concentration diagram (grains/cm^3)

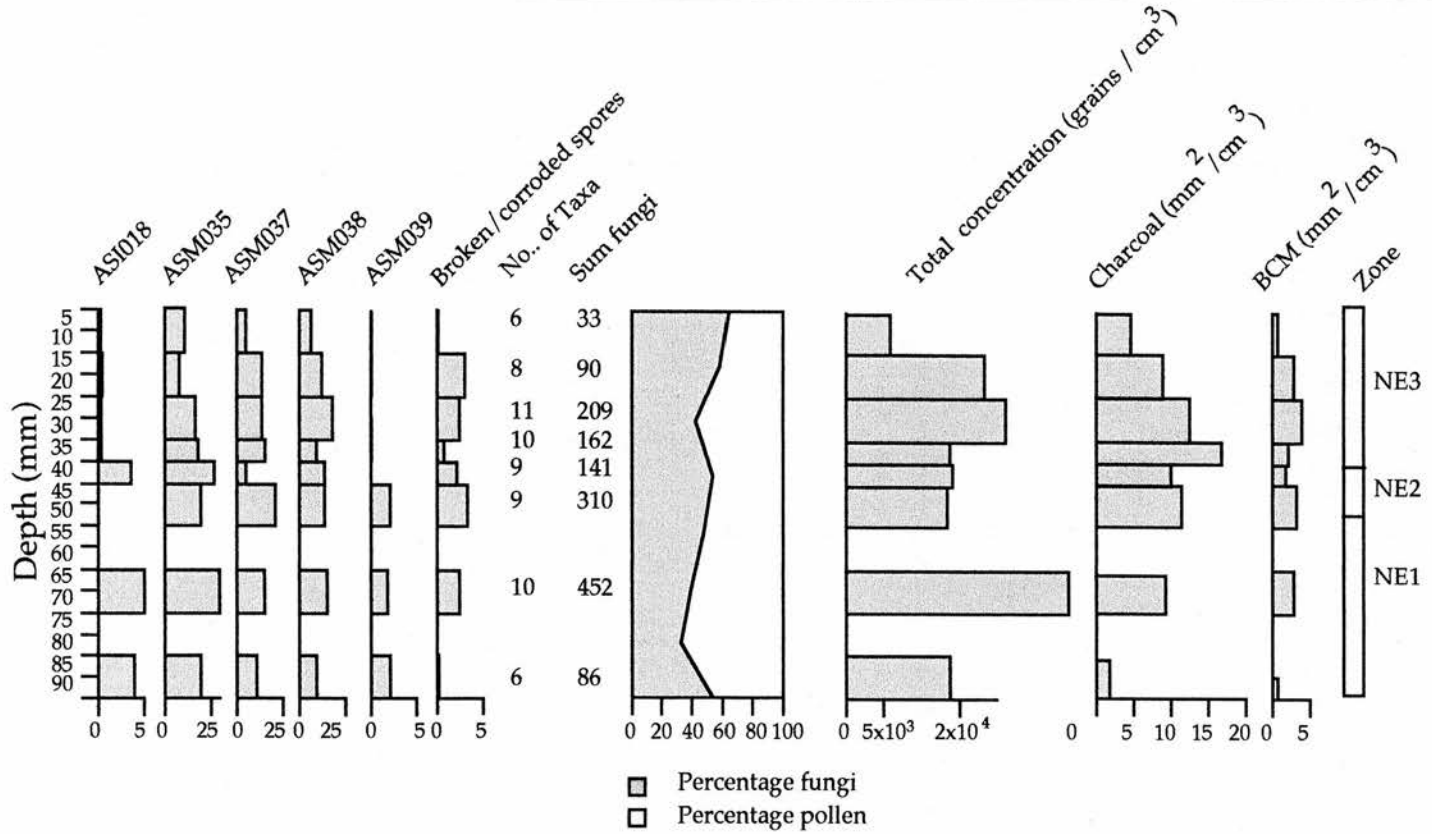


Fig. 5.35 Location E percentage NPF diagram (Σ_{fun}=TLP+NPF)

Sample	10	20	30	35	40	50	70	90
Betula	2	2	6	5	4	5	9	
Alnus	3	3	8	5		5	10	4
Quercus						1	1	
Calluna vulgaris	1	1	2		1			
Ericaceae								1
Rubiaceae			1	3	1	1		1
Ranunculaceae	1					1		
Asteraceae	1		1					
Asteraceae undiff.		1	2	2	2		1	
Caryophyllaceae				1				
Plantago lanceolata				4				
Plantago spp.			1	4	5	5	1	
Apiaceae								1
Alchemilla type		1			1			
Unknown		1	3			3		
Rosaceae						1		
Valeriana officinalis	1							
Urtica urens type				1				
Oxyria type					1			
Sphagnum		6	11	5		3	2	
Pteropsida			13	6	8	10	12	
Polypodium vulgare	1	3	1	2	3	2	1	

Table 5.9 Location E minor pollen taxa (n)

	10	20	30	35	40	50	70	90
ASI039			3	6		2	4	
ASI041	1	2						
ASM041			1		1		2	
MOI006			1					
MOI011			11					
MUI008		8						
IC008	1							

Table 5.10 Location E minor NPF types (n)

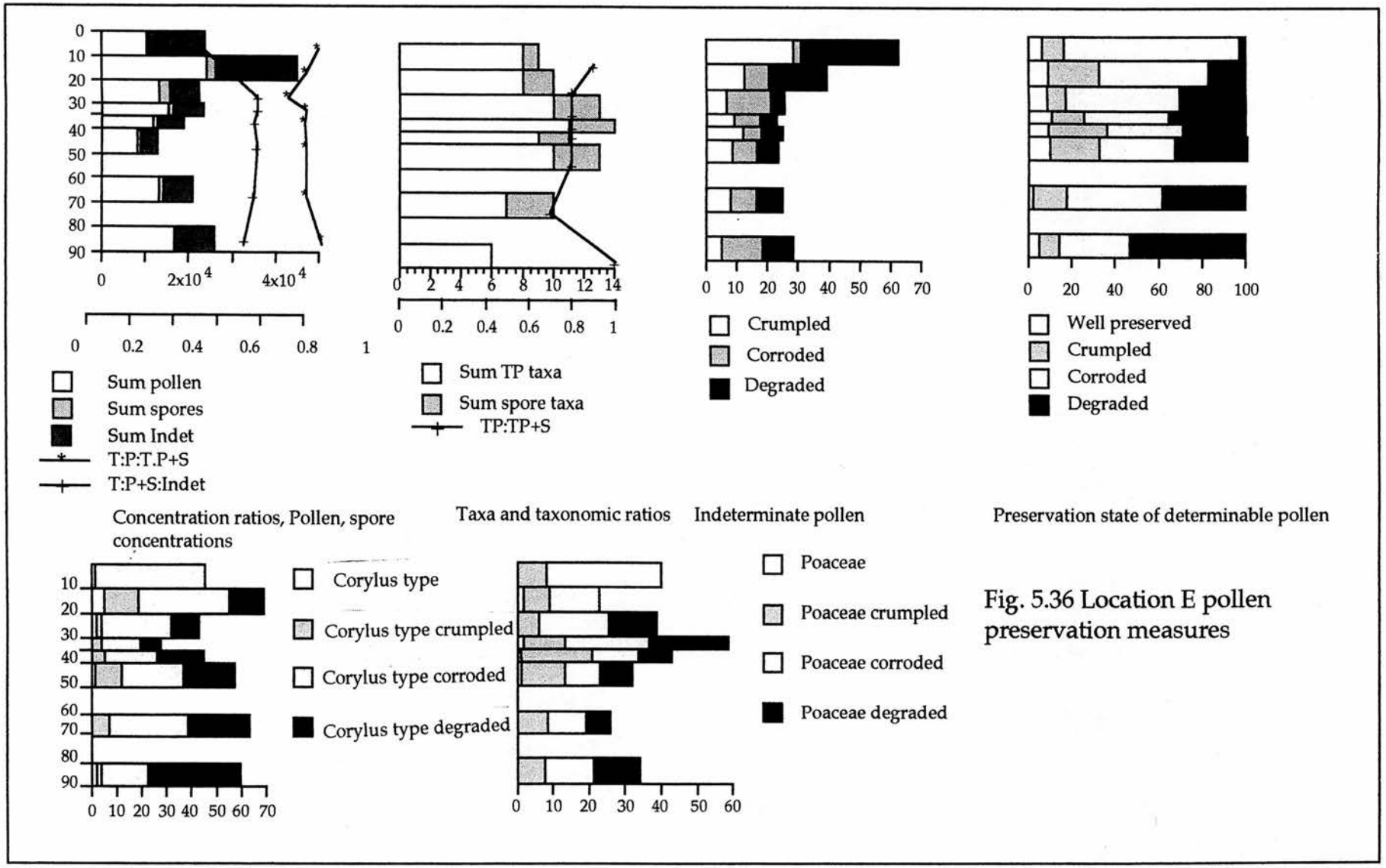


Fig. 5.36 Location E pollen preservation measures

Balnuaran of Clava South (ring cairn)

Site description

This monument was located in a patch of scrub to the south of the guardianship area. When excavated it was found to be a small ring cairn, comparable with the kerb cairn at Balnuaran of Clava North (Bradley forthcoming). It was a small *c.* 8m diameter ring cairn revetted with a kerb of contiguous small boulders, which in turn had a small external ramp (Fig 5.37 and Appendix 5 Figs. 16.2). The excavations at this site concentrated on the relationship between the kerb and the external ramp. From the excavation it appears that the monument was built in two phases. The first phase consists of a circular bank of rubble retained by a kerb of boulders, *c.* 45 cm high. The kerb overlay a buried soil sampled for palynofacies analysis. In the second phase the interior of the monument was excavated and the spoil placed around the outer kerb of the monument again sealing the soil surface. This soil surface was also sampled for soil palynofacies analysis.

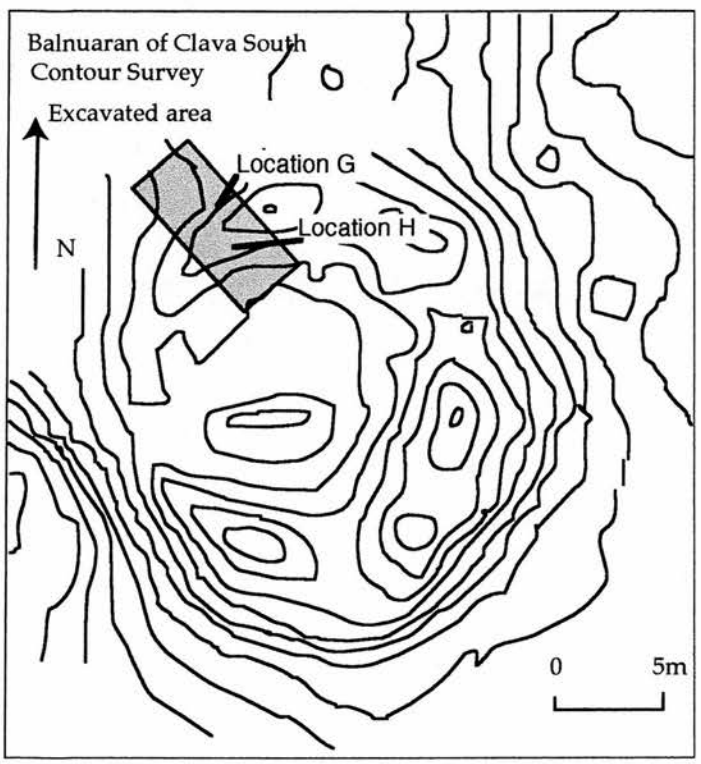


Fig. 5.37 Balnuaran of Clava South, Contour survey and excavated area

Location G Soil description and radiocarbon dates

The soils at this location as with those from the Balnuaran of Clava Central ring cairn are heavily bioturbated. They are described by Simpson and Davidson as dark brown organo-mineral soils which have been affected by burning and podsolisation (not illustrated) (Simpson and Davidson 1997). Two radiocarbon dates were obtained from this location:

AA-25228 2770 ± 45 uncal BP 2 σ 1027-827 cal BC

AA-25229 2420 ± 45 uncal BP 2σ 768-397 cal BC

The dates from the sealed surface beneath the core of the monument suggest a first millennium BC date for the construction of this part of the monument.

Location G Local Palynofacies assemblage zones. Pollen preservation and fungal hyphal analysis.

The small number of samples (4) and the broad similarities between them have led to these samples being grouped into one zone.

LPfAZ SRC G1 (0-40 mm)

These samples are dominated by Poaceae pollen with frequencies in excess of 45 % (Fig. 5. 38), these were the only samples in which phytoliths were observed in any quantity (Fig 5. 40). Percentage and concentration frequencies of *Corylus* type pollen and *Alnus* pollen, all decline in the topmost sample (0-10 mm) (Fig. 5.39). There is an increase in the amounts of palynodebris in sample 10-20 mm especially of charcoal, plant debris, phytoliths, and also in pollen concentrations. The microfossil assemblage is dominated by pollen microfossils between *c.*70-90% of the overall total. Occasional pollen grains of *Hordeum* type were located in these samples (Table 5.11).

Pollen preservation

Pollen preservation in these samples was good with large concentrations of pollen present in all samples (Fig 5.41). In common with many of the other samples much of this pollen showed signs of some deterioration with crumpling and corrosion present on many identifiable grains (Fig. 5. 41). The percentage of indeterminable pollen was under 20%. From the concentration data and the number of taxa per level there is a suggestion that

pollen was being concentrated in sample 10-20 mm. In this sample there is a rise in both the concentration of pollen and the number of taxa and a slight rise in the number of well preserved grains.

Hyphal frequency analysis

There is an increase of short hyphal fragments (0-21μm) down profile at the expense of medium size hyphal fragments (21-35, 35-61 μm) (Fig. 5. 42). This suggests that the soil was an active soil with movement of material down profile by large members of the soil fauna, where Oribitids then further comminuted these fragments.

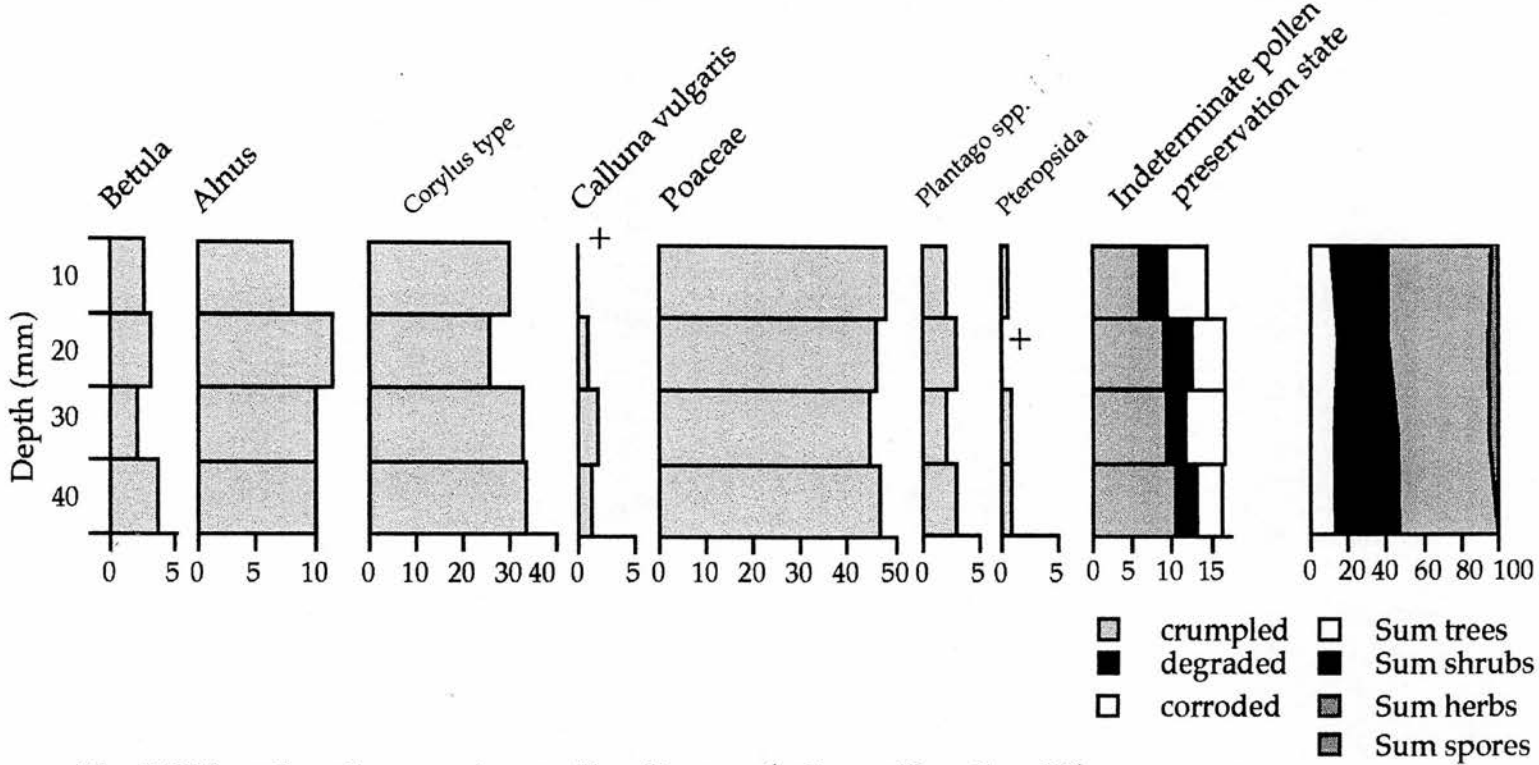


Fig. 5.38 Location G percentage pollen diagram (values of less than 2% are indicated by +)

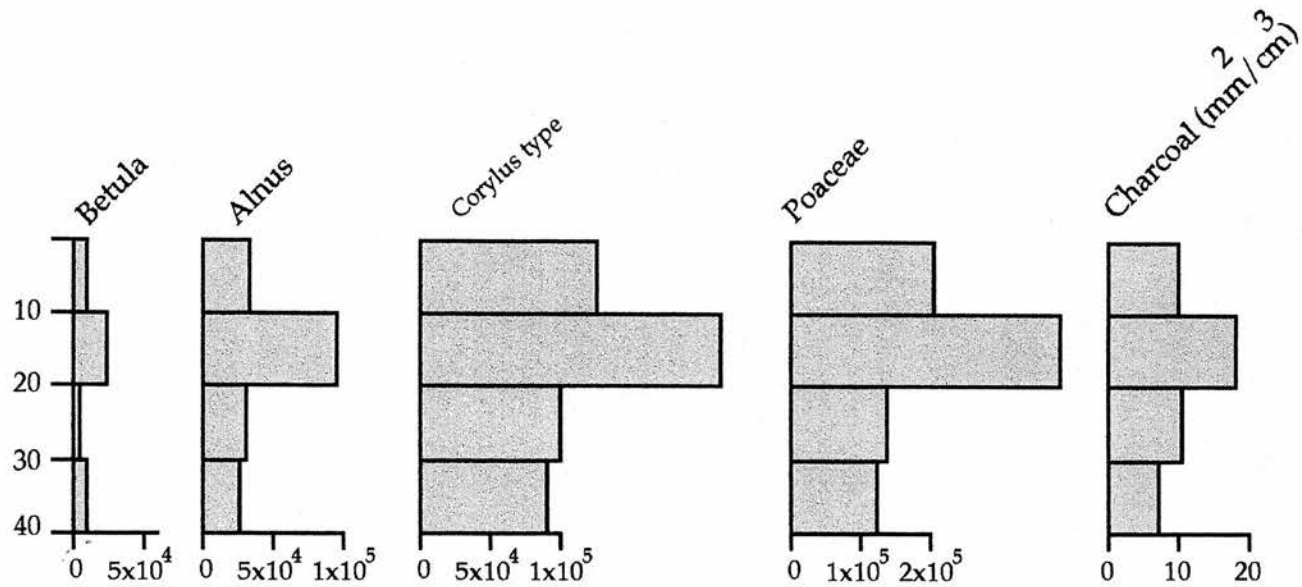


Fig. 5.39 Location G pollen concentration diagram(grains/cm^3)

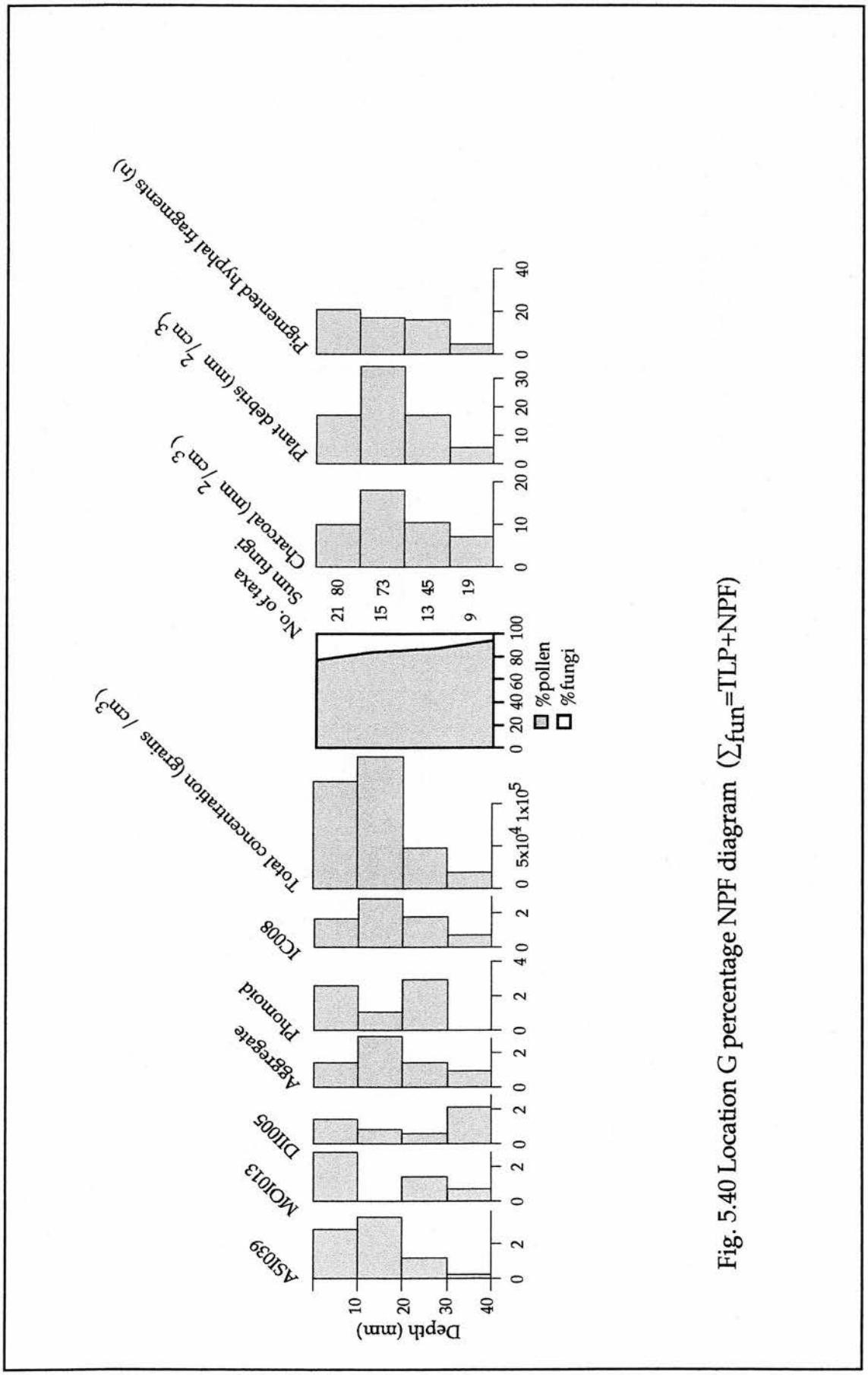


Fig. 5.40 Location G percentage NPF diagram ($\sum_{fun}$=TLP+NPF)

Sample	10	20	30	40
Pinus	1		1	
Quercus	1	2	1	
Salix	1			
Anthemis type	3			
Artemisia	5	4		
Aster type	1	1	1	
Caryophyllaceae	1	2		
Cirsium type	2			
Asteraceae lactucoideae		4		
Asteraceae undiff.	1	6	2	3
Crassulaceae	1			
Ericales		1		
Rubiaceae	2	2		1
Hordeum type	1	3	5	
Lotus type			1	
Plantago lanceolata		4		
Plantago spp.	6	7	6	8
Primula veris type		1	2	
Ranunculaceae		3	1	
Rosa type		1	1	
Succisa pratensis		2		
Apiaceae	2	1	1	
Unknown	1	2	1	1
Urtica urens type		2	2	
Valeriana		1		
Valeriana officianalis		1		
Pteropsida	4	4	5	5
Polypodium vulgare	3	5	2	3
Sphagnum		2		
Pteridium aquilinum	1	2	1	

Table 5.11 Location G minor pollen taxa (n)

Sample	10	20	30	40
ASI027	1			
ASI041	1			
ASM036	1			
ASM037	1			1
DII004	6			
DII007	4	2	1	
DII008	4	1	2	
IC009		2	5	
MOI002			1	
MOI006	3			
MOI007	2	1		
MOI014	1	6		1
MOI017	4	2	2	
MOI018	1		1	1
MOI019	1		1	2
TRI002	1			
Broken spores	4	1		
Toruloid fragment		1		

Table 5.12 Location G minor NPF types (n)

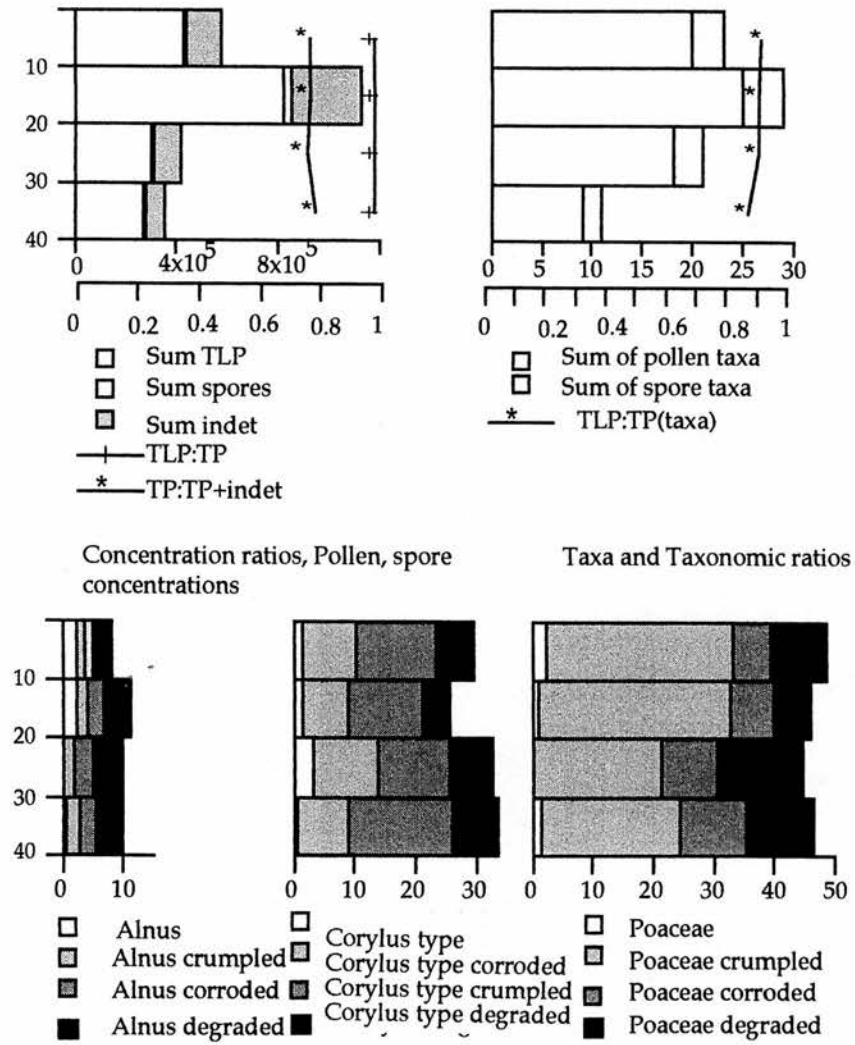


Fig. 5.41 Location G pollen preservation measures

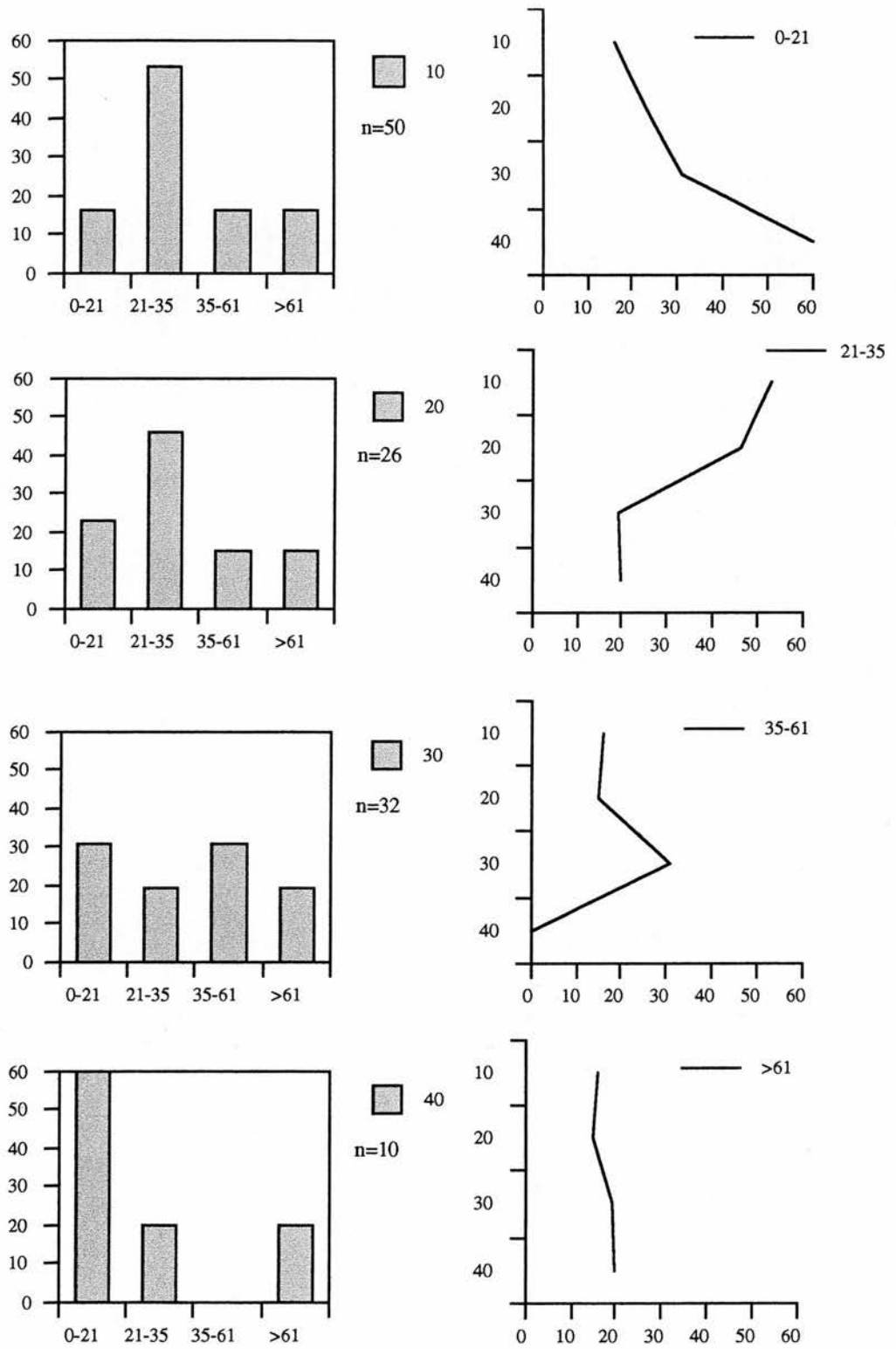


Fig. 5.42 Location G fungal hyphal length (μm) frequency analysis

Location H Soil description and radiocarbon dates

The soils at this location as with those from the Balnuaran of Clava Central ring cairn are heavily bioturbated. They are described by Simpson and Davidson as dark brown organo-mineral soils which have been affected by burning and podsolisation (not illustrated) (Simpson and Davidson 1997). Two radiocarbon dates were obtained from this location:

AA-25226 2680 ± 45 uncal BP 2 σ 917-798 cal BC

AA-25227 2745 ± 45 uncal BP 2σ 1002-814 cal BC

The dates from the sealed surface beneath the outer extension of the monument suggest a first millennium BC date for the construction of this part of the monument.

Location H Local Palynofacies assemblage zones. Pollen preservation and fungal hyphal analysis.

The small number of samples (4) and the broad similarities between them have led to these samples being grouped into one zone.

LPfAZ SRC H1 (0-40 mm)

These samples are dominated by Poaceae at *c.* 50 % of TLP, with *Corylus* type and *Alnus* as minor components (Fig. 5.43). The microfossil assemblage is dominated by NPF types at *c.* 40-70% of the overall assemblage (Fig. 5.45). The NPF assemblage is dominated by fungal spore types ASM006, ASM020, (Figs. A5 3.5, 3.6). , the diseptate types DII005, DII008, (Figs. A5 6.8, 6.11), and the monoseptate types MOI014, MOI017, and MOI019, (Figs. A5 5.14, 6.2, 6.3). Levels of plant debris, pigmented hyphae, and charcoal are greatest in sample 10-20 mm. Sample 10-20 mm has the highest number of pollen microfossils, and a higher pollen concentration than the other samples (Fig 5.44). Occasional pollen grains of *Hordeum* type were located in these samples (Table 5.13), minor NPF taxa are tabulated in Table 5.14.

Pollen preservation

Pollen preservation as measured by concentration appears excellent, pollen concentrations values are relatively high (Fig 5.46). On the measures employed in the study this is a well preserved sequence, with high levels of well preserved

pollen. Levels of indeterminate pollen are however relatively high at 15-25 %.

Hyphal frequency analysis

There is little evidence for a clear trend in the data as the frequency of the shortest fragments 0-21 μm is highly variable from level to level, suggesting equal importance of macro and micro-arthropods within the soil profile (Fig 5. 47).

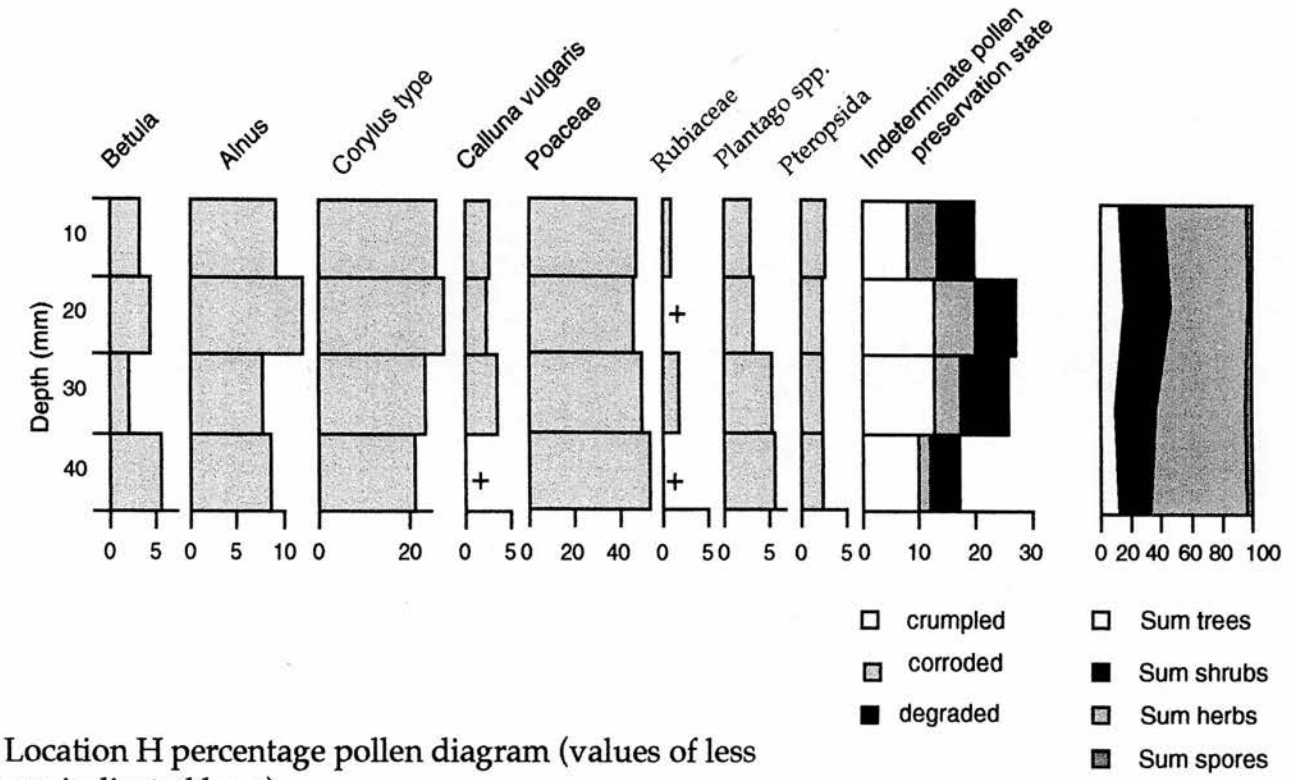


Fig 5.43 Location H percentage pollen diagram (values of less than 2% are indicated by +)

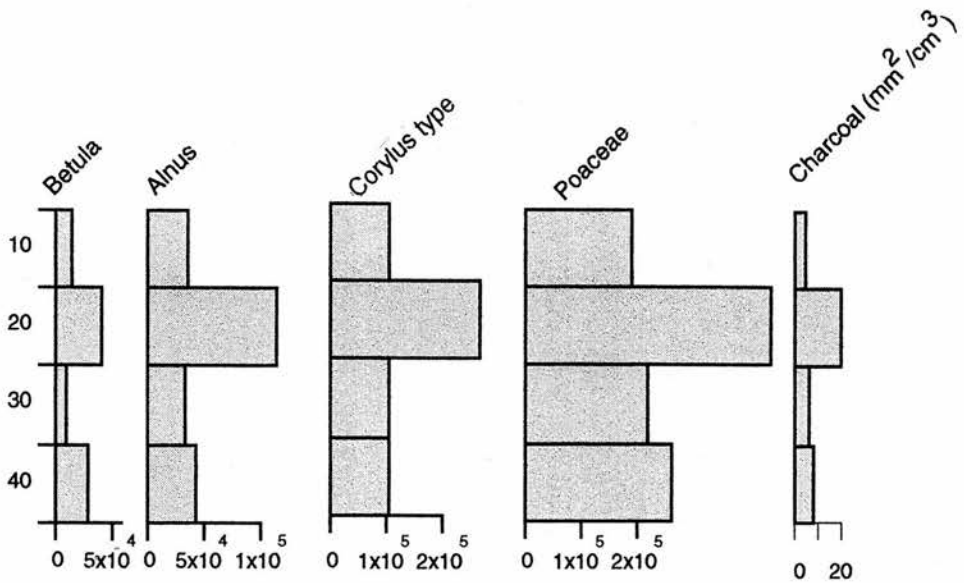


Fig. 5.44 Location H pollen concentration diagram (grains/cm^3)

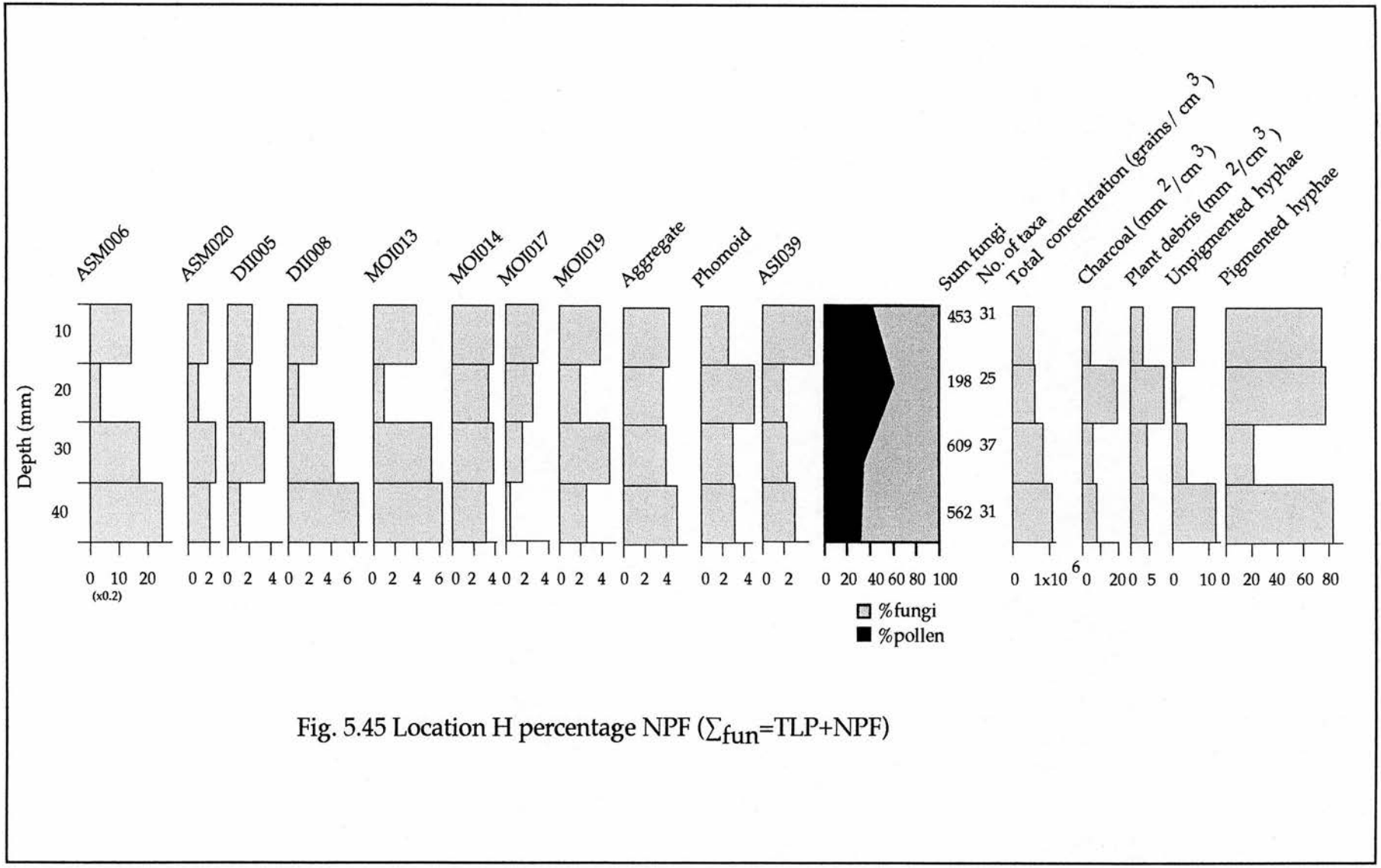


Fig. 5.45 Location H percentage NPF (Σ_{fun}=TLP+NPF)

Sample	10	20	30	40
Pinus	2	1	1	0
Quercus	2	1	0	1
Salix	0	0	1	0
Ericales	2	1	1	2
Rubiaceae	3	1	6	1
Ranunculaceae	3	0	2	1
Asteraceae lactucoideae	1	2	3	2
Asteraceae undiff.	5	0	2	1
Plantago lanceolata	0	1	1	1
Apiaceae	0	0	1	0
Hordeum type	3	0	2	0
Artemisia	1	2	1	1
Plantago spp.	9	10	16	14
Primula veris type	1	0	0	0
Valeriana	1	0	0	1
Urtica type	0	1	0	0
Oxyria type	0	0	0	0
Aster type	1	0	2	0
Caryophyllaceae	3	0	1	0
Cirsium type	0	1	0	0
Potentilla type	0	0	2	0
Cyperaceae	1	0	1	0
Succissa pratensis	0	0	1	0
Chenopodiaceae	0	0	0	1
Pteridium aquilinum	0	1	2	1
Unknown	0	1	0	2

Table 5.13 Location H minor pollen taxa (n)

Sample	10	20	30	40
ASD003	0	0	1	0
ASD005	0	0	3	0
ASI003	1	0	1	3
ASI010	0	0	2	1
ASI021	2	0	1	0
ASI024	1	0	3	0
ASI027	0	1	0	0
ASI029	0	2	0	0
ASI030	0	0	1	0
ASI040	0	0	2	0
ASI041	2	1	8	3
ASM001	0	0	4	0
ASM004	0	0	0	1
ASM010	0	0	1	0
ASM018	3	0	0	0
ASM037	1	1	0	0
ASM041	0	0	1	0
ASP001	0	0	1	0
DII002	0	0	0	2
DII003	0	8	11	1
DII006	5	7	0	12
IC009	1	2	5	2
IC011	1	0	5	2
MOI001	7	0	0	0
MOI002	2	0	0	4
MOI007	2	0	0	0
MOI012	0	0	1	1
MOI016	0	1	0	0
MUI003	0	0	0	1
MUI008	1	0	3	1
Toruloid fragment	2	1	1	0
TRI003	0	0	1	2
TRI007	1	0	0	0

Table 5.14 Location H minor NPF types (n)

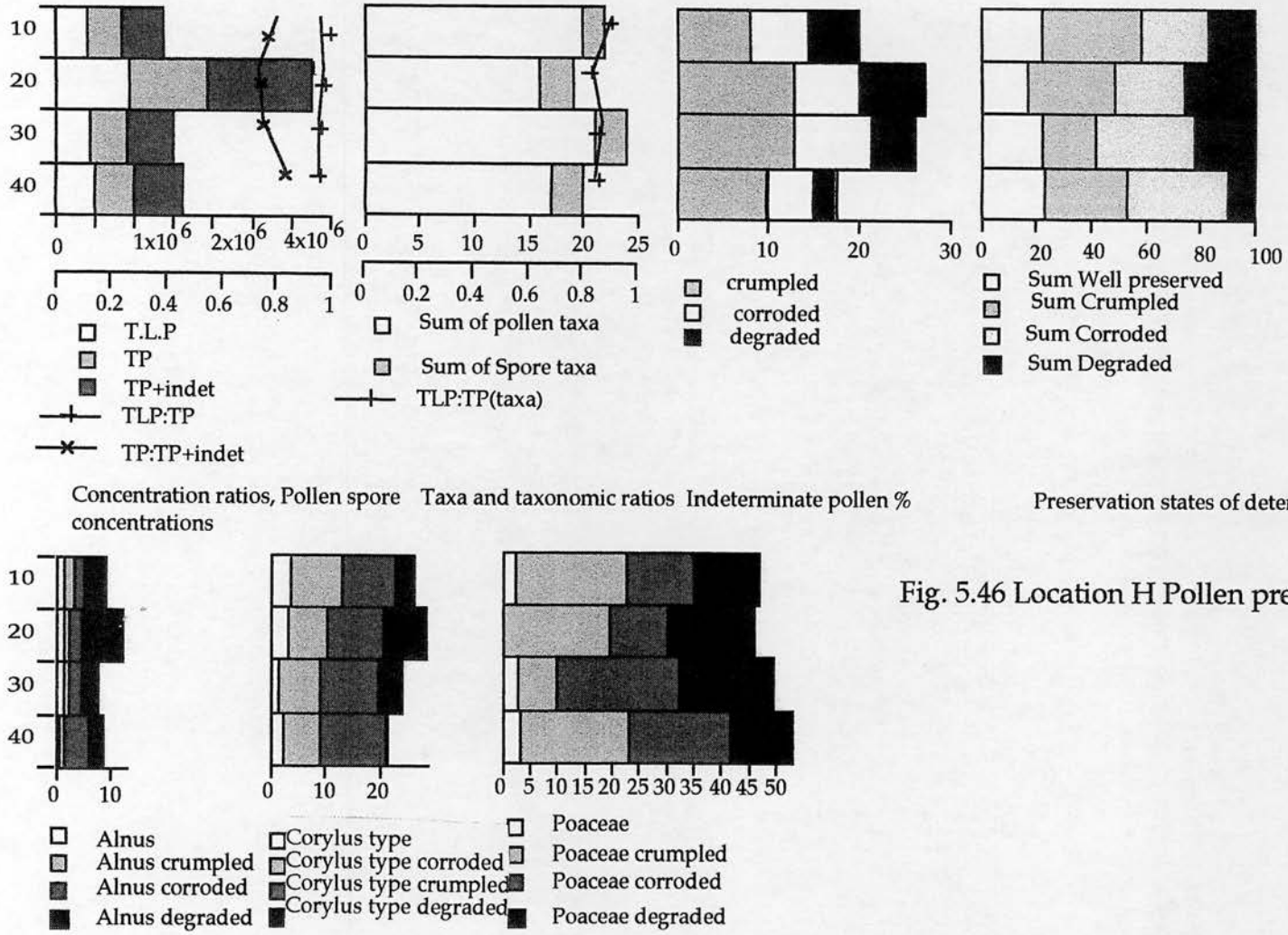


Fig. 5.46 Location H Pollen preservation diagram

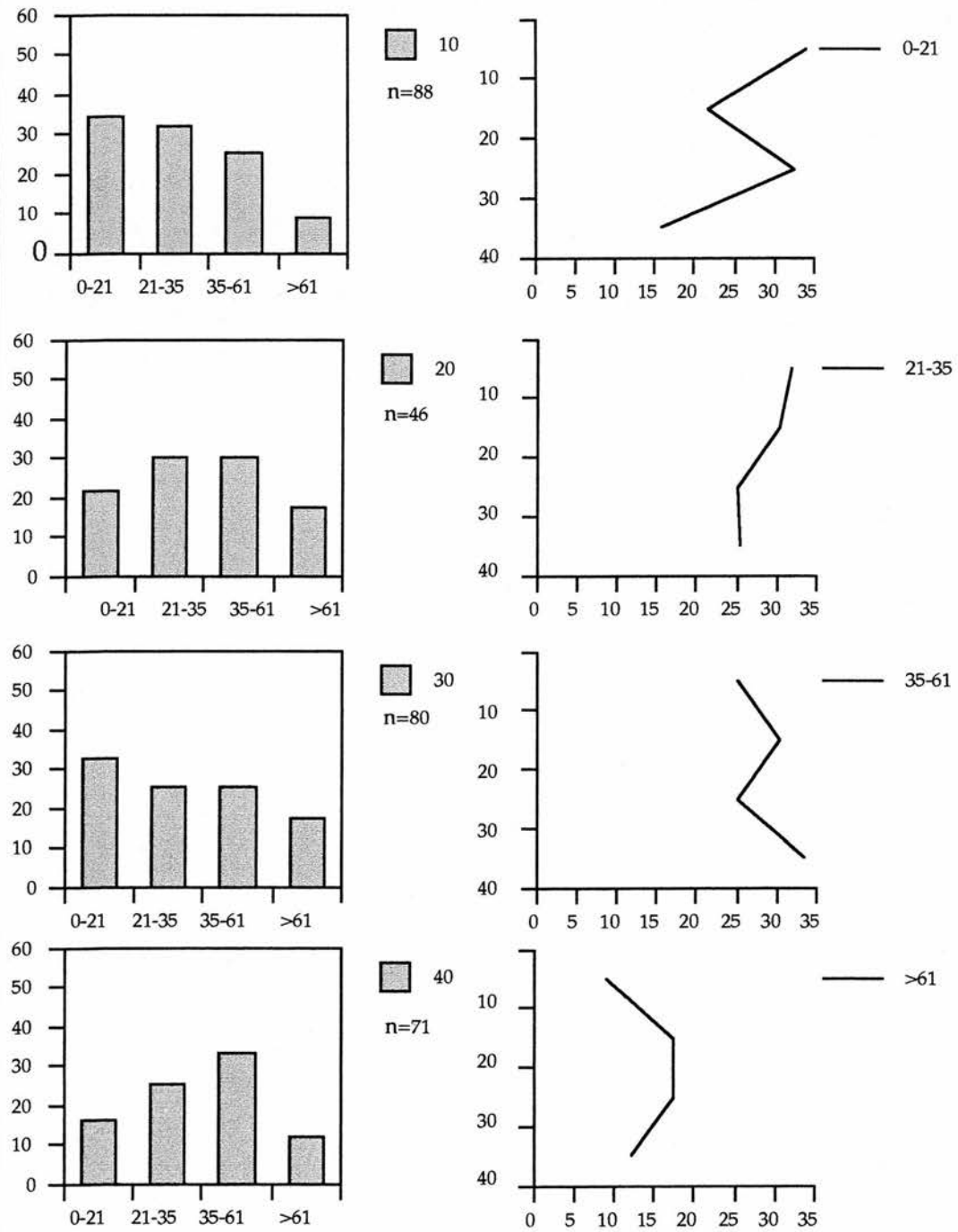


Fig 5.47 Location H fungal hyphal analysis

Section 3: Discussion.

Introduction

Section 3 is itself divided into five sub-sections, dealing with what is known of the taphonomy of the deposits analysed, the palaeoenvironmental interpretation at each location, a discussion of the phasing of the monuments a overall interpretation of the environments of the sites and finally a conclusion. This structure was chosen because of the important role taphonomic processes play in producing soil pollen assemblages (Dimbleby 1985, Andersen 1988). By understanding the soil processes that have affected the samples e.g. through mixing, differential pollen preservation etc. biases in the data can be identified and accounted for, in the subsequent interpretation.

Each location is interpreted separately as they represent individual fragments of past vegetation cover; each has separate histories and has been affected by different processes, their unity derives from being buried beneath monuments in a similar geographical location. Similarities between the different locations need to be demonstrated by similar periods of burial, soil processes and vegetation history. The similarities between the sites are first considered in terms of taphonomy, then chronology and finally vegetation. The unpublished nature of the excavation of the sites means that this is difficult to critique but it is clear that the dating particularly of the Central ring cairn and South-west passage grave are problematic. Finally, an overall interpretation of the landscape and possible economy at the sites, based on the taphonomic, environmental and chronological information is proposed.

Taphonomy

The following discussion of the taphonomy of the deposits begins with a consideration of the differences in the fungal spore and pollen data. This is followed by a discussion of the possible taphonomic processes that have produced these differences. Finally, a synthesis of all the data is presented using the palynofacies analysis with evidence from the soil micromorphology and charcoal analysis. To make the discussion easier to follow a series of abbreviations is used to indicate the cairn from

which samples came: Balnuaran of Clava South-west passage grave =SWPG, Balnuaran of Clava Central ring cairn = CRC, Balnuaran of Clava North-east passage grave =NEPG, Balnuaran of Clava South ring cairn = SRC.

Pollen and fungal spore assemblage differences

The pollen analysis from the monuments suggests a broadly similar picture of the environment between sampling sites from similar monuments and periods e.g. the rise in *Calluna vulgaris* pollen at Locations B (SWPG external ramp) (Fig. 5.15), C and D (CRC external ramp and cairn core respectively) (Figs. 5.21 and 5.26), and the overall similarities between Locations C and D (CRC) from the beginning of the second millennium BC and their clear difference to Locations G and H (SRC external ramp and core)(Figs. 5.38 and 5.43) from the end of the second millennium BC. Therefore intra-monument variation of the pollen spectrum is less than inter monument variation.

The fungal spore analysis, however, produces a more complex and surprising picture. Where applicable, inter-monument variation of the NPF assemblage is less than intra-monument variation of the NPF assemblage, i.e the fungal spore assemblage from Location C (CRC) (Fig. 5..23) has greater similarities to Location H (SRC)(Fig. 5.45) situated a 100 m away in space and 1000 years in time, than it does to Location D (CRC)(Fig. 5.28) less than 5 m away and from the same period of construction. Similar results are also seen at the other cairns.

This unexpected result in the distribution of fungal spore assemblages may be the result of chance variation or may represent significant patterning within the data. The variation over short distances in fungal spore assemblages e.g. between Locations G and H (SRC)(Figs. 5.40, 5.45) or C and D (CRC) (Figs. 5.23, 5.28) is reminiscent of that observed between samples from Meldon Hills (Chapter 3) and from modern samples as reported by Clarke (1994). What is unexpected are the similarities between the fungal spore assemblages between the external ramps (Locations B (SWPG), C (CRC) and H (SRC))(Figs. 5.17, 5.23, and 5.28) the ring cairn cores (Locations D (CRC) and G (SRC))(Figs. 5.28, 5.40) and the non-bioturbated passage grave deposits (Locations A (SWPG) and E (NWPG)) (Figs. 5.12 and 5.35).

Fungal spore analysis within palaeoecology is in its infancy (van Geel 1986, Clarke 1994), and problems with using non-pollen microfossil assemblages have been discussed in Chapters 2 and 4. Principally these problems relate to a lack of detailed taxonomic information of fungal spore types (van Geel 1978, Clarke 1994). The following discussion uses an assemblage approach to fungal spore and non-pollen microfossil assemblages in order to draw conclusions about their distribution. To explore this situation further a number of multivariate statistical techniques were used as described in Chapter 3.

Cluster analysis

The results of the Cluster analysis are presented in Fig 5. 48. The cluster analysis confirms the immediate visual impression of the results. Overall the samples divided into three main clusters. The samples from beneath the rubble ramps Locations B (SWPG), C (CRC) and H (SRC) , formed a group of clusters within which Location B (SWPG) and H (SRC) are very closely grouped, another cluster of samples predominately from Location E (NEPG) and A (SWPG) which are less tightly grouped, and a cluster from Locations D (CRC) and G (SRC).

This result suggested that the fungal spore spectra from the ramps represented a discrete assemblage. It also suggested that ring cairns and passage graves had discrete NPF spectra. For this reason Principal Components Analysis was used to further investigate the NPF assemblages.

Principal Components Analysis

The Principal Component Analysis suggests that the data has a large amount of variance along a number of principal components. The first seven components account for 70% of the variance (Table 5.15). This indicates a complex structure to the data, and would argue for a degree of caution in interpretation (Birks and Gordon 1985).

The first principal component indicates variation along an axis representing positive values for mono and diseptate fungal spore types (e.g. MOI017, DII008) and weakly negative values for dark monoporate fungal spore types such as ASM035 (Table 5.16, Fig. 5.50). The second principal component is positive for types such as fungal segment frag-

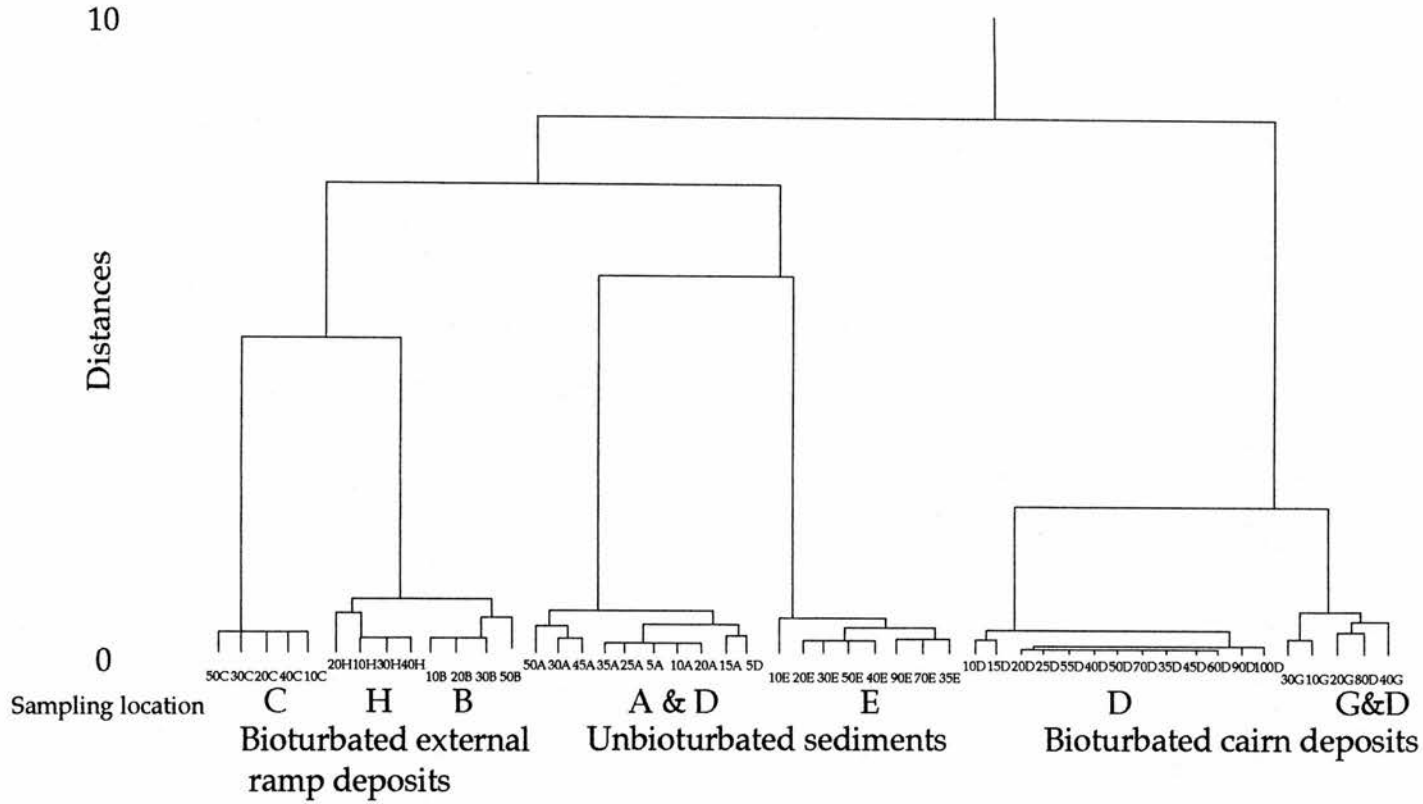


Fig. 5. 48. Results of Wards method cluster analysis on fungal spore data from sites at Balnuaran of Clava

Component	1	2	3	4	5	6	7	8	9
Percentage	21	14.5	10.7	8.97	6.93	5.54	4.16	3.24	2.96

Table 5.15 Percentage component scores of samples for fungal spore data from sampling locations at Balnuaran of Clava

Sample	1.000	2.000	3.000	4.000	5.000	6.000	7.000	8.000	9.000
10b	-0.132	0.006	0.000	-0.859	-0.891	-0.139	-0.135	-0.796	0.108
20b	-0.171	-0.028	-0.250	-0.803	0.096	0.030	0.069	-0.355	-0.052
30b	-0.297	-0.222	-0.173	-0.716	-0.542	-0.030	-0.477	-0.508	0.310
50b	-0.080	-0.632	0.075	-0.640	-0.572	0.149	-0.910	-0.490	1.028
10c	1.496	1.262	-0.109	-0.148	0.425	-0.267	2.333	1.241	-3.202
20c	2.372	2.393	-0.362	0.931	-0.348	0.935	2.158	-3.329	0.081
30c	1.736	2.334	-0.428	0.219	0.001	0.118	-0.361	-1.653	1.402
40c	2.374	2.908	-0.346	0.173	0.663	-0.689	-2.352	2.971	0.992
50c	1.306	1.685	-0.224	-0.187	0.299	-0.102	-0.753	1.555	-0.122
10h	2.062	-2.034	0.684	0.184	0.051	-0.177	0.291	-0.572	-2.099
20h	0.571	-0.564	0.173	-0.337	-0.486	0.028	0.586	-0.621	-1.618
30h	2.994	-2.992	0.981	0.424	0.187	0.273	0.691	0.615	-0.139
40h	2.567	-2.658	0.792	0.671	-0.316	-0.037	-1.484	0.048	2.566
05a	-0.688	-0.463	-1.417	2.466	0.781	-0.696	0.330	0.146	0.933
10a	-0.561	-0.339	-1.217	1.769	-0.629	0.331	-0.328	-0.387	-0.098
15a	-0.541	-0.452	-1.727	2.336	1.419	-0.255	-0.071	-2.016	0.315
20a	-0.673	-0.330	-0.813	2.186	-0.444	1.370	0.687	1.914	0.085
25a	-0.445	0.036	-0.403	0.190	-0.923	0.642	0.051	0.024	0.143
30a	-0.634	0.053	-0.165	0.932	-1.908	2.054	0.789	1.409	0.821
35a	-0.517	-0.091	-0.596	0.703	-1.372	0.953	0.193	0.459	0.184
45a	-0.525	0.130	-0.073	-0.050	-1.751	0.782	0.242	0.942	-0.157
50a	-0.500	0.101	-0.466	0.964	-1.497	1.330	0.354	0.492	0.127
05d	-0.596	-0.291	-1.282	2.162	0.734	-2.587	-2.136	0.137	-2.897
10d	-0.496	0.023	-0.647	-0.177	0.337	-0.134	-0.636	-0.056	-0.442
15d	-0.285	-0.143	-0.201	-0.525	-0.040	-0.590	-0.394	-0.663	-0.027
20d	-0.214	-0.038	-0.110	-0.804	-0.476	-0.345	-0.216	-1.274	0.559
25d	-0.359	0.000	-0.296	-0.565	0.255	-0.639	-0.240	-0.595	0.367
35d	-0.479	-0.115	-0.591	-0.596	0.917	-0.003	-0.524	-0.333	0.095
40d	-0.429	-0.107	-0.498	-1.001	1.160	0.264	-0.155	-0.222	0.667
45d	-0.439	0.048	-0.237	-0.952	0.068	0.173	-0.126	-0.160	0.216
50d	-0.418	0.009	-0.128	-0.886	-0.193	-0.135	-0.107	-0.188	-0.008
55d	-0.444	-0.051	-0.304	-0.733	0.166	-0.250	-0.273	-0.350	-0.060
60d	-0.410	-0.080	-0.504	-0.881	1.221	0.317	-0.243	-0.048	0.574
70d	-0.337	-0.443	-0.793	-0.982	2.706	0.543	0.125	-0.058	0.924
80d	-0.335	-0.203	-0.181	-0.753	-0.086	-0.071	-0.115	-0.268	-0.612
90d	-0.302	-0.550	-0.707	-0.946	2.708	0.926	2.412	1.532	0.518
100d	-0.355	-0.288	-0.451	-0.900	1.301	0.513	1.535	0.958	0.012
10e	-0.441	0.138	0.154	-0.797	-1.089	-0.076	-0.122	-0.183	-0.459
20e	-0.457	0.318	0.551	-0.576	-0.937	-0.052	-0.042	-0.178	-0.296
30e	-0.740	0.310	1.640	0.749	-0.850	-4.714	3.052	0.784	2.159
35e	-0.633	0.278	1.150	-0.009	-0.026	-0.254	-0.171	-0.199	-0.135
40e	-0.566	0.128	1.065	-0.088	-0.053	-0.823	0.033	-0.197	-0.045
50e	-0.857	0.503	2.676	0.857	0.798	0.392	-0.066	-0.052	0.156
70e	-1.125	0.832	4.362	1.792	2.015	1.658	-1.003	-0.429	-0.518
90e	-0.562	0.291	1.060	-0.360	-0.493	0.480	-0.430	-0.298	-0.664
10g	0.108	-0.311	0.201	-0.705	-0.726	-0.627	-1.001	0.734	-0.146
20g	-0.049	-0.351	0.050	-0.881	-0.248	-0.377	-0.536	0.128	-0.773
30g	-0.220	0.008	-0.021	-0.900	-0.476	-0.051	-0.448	0.334	-0.051
40g	-0.272	-0.020	0.104	-0.951	-0.936	-0.138	-0.073	0.054	-0.722

Table 5.16 sample scores for the first seven principal components

	1	2	3	4	5	6	7	8	9
MOI014	0.855	0.071	-0.059	-0.242	0.152	0.122	0.175	0.062	0.048
DII007	0.832	0	0.018	-0.049	0.25	-0.187	-0.211	0.094	0.064
MOI018	0.782	0.013	0.025	-0.012	0.13	0.234	0.32	0.132	-0.078
MOI017	0.781	-0.087	0.08	0.114	0.23	-0.208	-0.173	0.034	0.124
DII008	0.737	-0.05	0.044	0.257	0.03	-0.295	-0.121	-0.081	0.139
FUNSEG	0.617	0.27	-0.239	-0.608	0.131	0.133	-0.016	0.043	0.001
ASI003	0.612	0.256	-0.239	-0.549	0.047	0.084	0.023	0	-0.044
ASM020	0.581	0.172	-0.216	-0.15	-0.394	-0.101	-0.083	-0.338	0.133
MOI019	0.577	-0.184	0.223	0.42	0.032	0.186	0.474	-0.115	-0.064
ASI039	0.021	-0.755	0.215	-0.007	0.123	-0.311	0	0.247	0.005
AGGRE	0.205	-0.724	0.406	0.166	0.157	0.17	0.12	0.075	0.11
IC008	-0.371	-0.722	-0.048	-0.335	-0.242	0.011	-0.171	-0.102	-0.005
ASM038	-0.382	0.714	0.442	0.084	0.079	0.044	-0.025	0.09	-0.177
IC009	-0.363	-0.676	0.019	-0.338	-0.163	0.039	-0.172	0.262	0.018
ASM037	-0.262	0.586	0.651	-0.063	0.009	-0.035	0.111	0.025	0.102
ASM035	-0.334	0.572	0.618	-0.077	0.01	-0.134	0.145	-0.033	0.173
ASM004	-0.393	-0.53	-0.197	-0.112	0.002	0.167	0.085	0.236	0.322
DII005	0.246	-0.502	0.387	0.199	0.135	0.503	0.277	-0.198	-0.075
ASM001	-0.425	0.052	-0.632	0.226	0.394	-0.035	0.189	-0.106	0.139
DII006	0.065	0.221	-0.532	0.262	0.284	0.235	-0.045	0.12	0.392
PHOMOID	-0.284	0.226	-0.51	0.495	0.26	0.09	-0.17	0.057	-0.136
MUI008	0.429	0.363	-0.07	-0.547	0.123	0.174	-0.034	0.133	-0.125
MOI013	0.378	0.148	-0.395	0.519	-0.435	-0.064	0.178	0.069	0.082
ASM006	0.468	0.09	-0.181	0.209	-0.713	-0.188	0.022	-0.145	-0.001
ASM007	0.112	0.018	-0.102	0.287	-0.576	-0.088	0.223	0.382	-0.264
ASM036	-0.396	-0.016	0.068	-0.171	0.207	-0.578	0.338	-0.155	-0.163
MOI012	-0.119	-0.246	0.082	-0.089	-0.13	0.391	-0.228	-0.577	-0.053
ASM041	-0.233	0.281	-0.321	0.321	0.265	0.256	-0.248	0.055	-0.407
ASM039	-0.259	0.494	0.381	0.067	0.039	0.045	0.008	0.012	0.376
MOI004	0.449	-0.285	0.344	0.272	0.392	-0.077	-0.112	-0.07	-0.23
ASD005	-0.08	-0.135	-0.344	-0.451	0.221	-0.412	0.312	-0.103	-0.178
ASM029	-0.394	-0.129	-0.473	0.037	0.26	-0.171	0.343	-0.227	0.106
DII004	0.393	-0.149	0.193	0.382	0.24	-0.441	-0.352	-0.083	0.021

Table 5.17 Component loadings for fungal spore types on the first two principal components

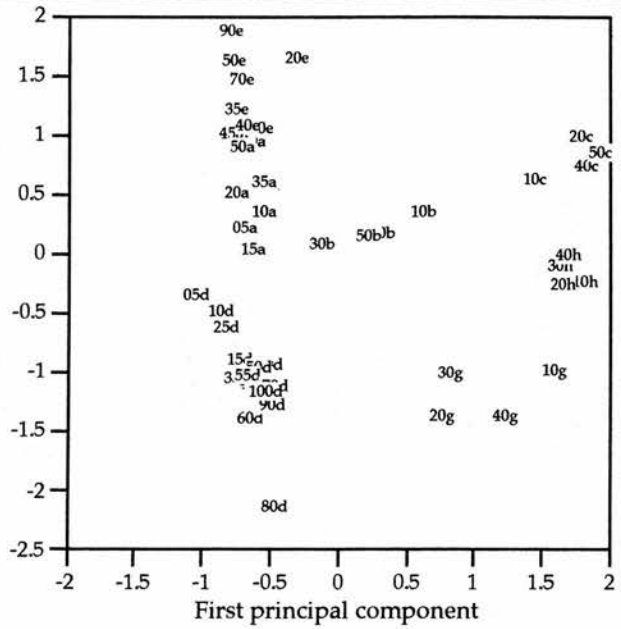


Fig. 5.49 Plot of the first two principal components for selected fungal taxa from Balnuaran of Clava

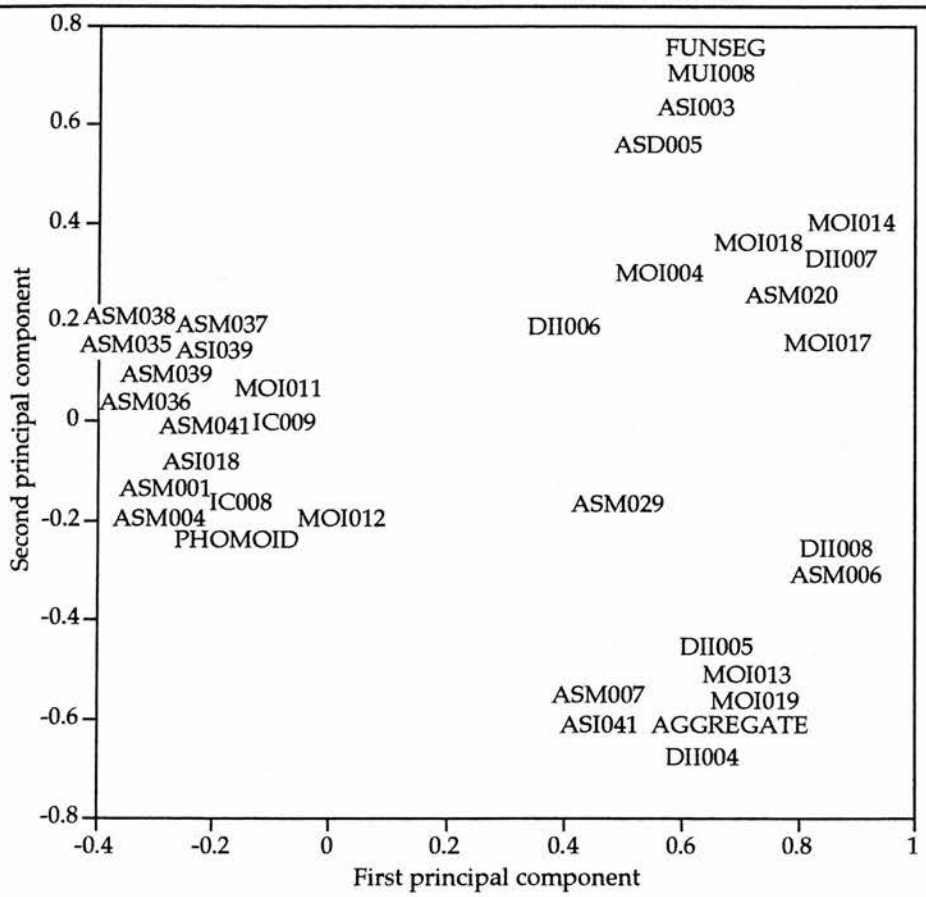


Fig. 5.50 Component scores for selected taxa on the first two principal components

ments, fungal spore type MUI008 and also mono and diseptate fungal spores. Much of the variation along the second principal component is amongst mono and diseptate types, but fungal spore types ASM006, ASM007 and ASI041 are all negatively loaded for this factor.

The samples from Locations B (SWPG), C (CRC), G (SRC) and H (SRC) are all with the exception of B30, located on the positive axis of factor one. Locations B (SWPG), C (CRC) and H (CRC) also plotted together in the Cluster analysis. The samples from beneath the external ramps are therefore positively loaded along the first principal component reflecting the prominence of mono and diseptate spore spore types in these samples, they do not show major variation along the second principal component being either weakly negative (Location H (SRC)) or weakly positive (Locations B (SWPG) and C (CRC)) (Fig. 5.49). This may be due to the over representation of fungal segment fragments, and fungal spore types MOI014, MOI017, MOI018 and DII007, at Locations C and H and fungal spore types ASM006 and ASM007 at Location B.

Samples from Location G (SRC) are also strongly loaded on the first principal component but are strongly negatively loaded on the second principal component. Samples from Locations A (SWPG), E (NEPG) and D(CRC) have negative values on the first principal component but on the second principal component they are split with samples from Location D (CRC) scoring negative for factor two whilst those from Locations A (SWPG) and E (NEPG) are positive for this factor.

The samples therefore fall into six broad groups on the first two principal components reflecting their differing locations within the various cairns analyzed. However, the samples from different locations beneath the same monuments do not group together. Examining the groups it may be suggested that samples from Location A (SWPG) , D (CRC) and E (NEPG) form a overlapping continuum of samples as do those from Locations C (CRC), and H (SRC), whilst Locations B (SWPG) and G (CRC) seem to stand alone. These groupings in the Principal Components Analysis are loose but suggest that the samples are reflecting similar underlying ecological conditions.

The results from the Cluster Analysis, Principal Components Analysis and a visual inspection of the data indicates that the samples

form three groups; samples from the external ramps (B, C and H) forming one group, samples from the core of the ring cairns (D and G) a second group and unbioturbated sediments from the passage graves a third (A and E). This grouping suggests that the results are more than stochastic patterns and that the assemblage approach to fungal spore analysis is valid in this case. It is worth remembering that the samples from locations B and C are from beneath monuments thought on archaeological grounds to have been constructed nearly a thousand years before the monument which seals location H. It is however, difficult to interpret the results because of the lack of ecological information relating to the spore types (see below). The following interpretation therefore is provisional and attempts to explain the observed pattern of fungal spore distribution in terms of taphonomic processes drawing on information from the pollen analysis and soil micromorphology.

Each of the above groups will be considered in turn below.

Group 1: The external ramps (Location B (SWPG), Location C (CRC), and Location H (SRC)

The first of the three groups to be discussed comprises samples from Locations B (SWPG), C (CRC) and H (SRC). Of these samples, those from Locations C and H are the most similar, their palynofacies assemblages being dominated by fungal spore taxa (*c.*70% of all identified microfossils). Of these the main taxa are the mono and diseptal types and fungal spore fragments, also important are fungal spore types ASM006, ASM007 and ASM020 (found at Meldon Hills in association with grassy heath on well drained soils). At Location B overall the amount of fungal remains present in the samples was lower (*c.*30 % of the palynofacies assemblage), and fungal spore types ASM006, ASM007 and ASM020 are the most important types at this location mono and diseptal types although present are in much lower proportions.

If, as discussed above, we assume that the fungal spore data at Locations C (CRC) and H (SRC) and also possibly Location B (SWPG) are reflecting broadly similar environmental or taphonomic conditions at each of the sampling sites, then the following probable explanations for the observed distribution of the fungal spore may be considered: 1) it is a result of later disturbance; 2) the NPF assemblage represents the broadly

similar environments present at the sampling sites during the construction of the rubble ramps; 3) a special pre- treatment of these areas which resulted in similar assemblages at the three locations; or 4) it is the result of the heterogeneous nature of dispersed fungal spore distributions. Or 5) some interaction of all four phenomena, or an unknown factor.

It is difficult in such an argument to avoid circularity. However four other lines of evidence are available: 1) the archaeological evidence; 2) the pollen evidence; 3) the palynodebris evidence; 4) the soil micromorphological evidence.

In the following argument the case for the distributions of fungal spores at the sampling sites being the result of later biological disturbance of the soil profile will be made first. This is followed by a discussion of why the other possible alternatives are less probable.

Samples from beneath the external ramps are broadly similar in taxa composition but the absolute numbers of fungal spore types varies with high numbers at Locations G and C and lower numbers at Location B, due to the absence of large numbers of mono-diseptate types. Further, to the similarities of their fungal spore spectra, these locations are also characterized as being heavily bioturbated (Simpson and Davidson 1997) and in addition contain unpigmented hyphal fragments.

The evidence from the palynodebris spectra appears to hold the key. During counting of hyphal fragments a number of unpigmented hyphal fragments were identified at each of the sampling locations beneath the external ramps. The presence of unpigmented hyphal fragments within these samples strongly suggests the intrusion of modern fungal communities into the samples probably as a result of root action. According to Andersen unpigmented hyphae are rapidly broken down in podsols and after a year pigmented hyphae form 80-90% of the population (Andersen 1984). The presence of unpigmented hyphae within the samples therefore indicates that the soil had active fungal organisms until recently. It is further likely that these hyphae would be involved in the production of conidial spores within the ground (Ellis and Ellis 1988, Griffin 1972, van Geel 1978, Dix and Webster 1995)). It should also be noted that these sampling locations were only vertically sealed, lateral penetration of the deposits by modern roots was both possible and

noticed during initial sampling at the ramps. Further, unpigmented hyphae were not noted at any of the other sampling sites.

Many of the fungal spore types identified at sampling Locations B (SWPG), C (CRC) and H (SRC) could be conidial in form, and therefore have developed *in-situ* in the soil; an example of this is van Geel's type 10, a conidial form, which is produced in the peat directly from the mycelium surrounding the roots of ericales (van Geel 1978 p. 58-61. It is therefore possible to suggest that the fungal spore assemblages at Locations B (SWPG), C (CRC) and H (SRC) represent later *in-situ* deposition of fungal spores after construction of the external ramps. This process, as the unpigmented hyphae indicate, may be continuing to the present day. Such an explanation may explain why the fungal spores at these widely spaced (chronologically and temporally) locations are so similar to each other, and so different to those located in the same monuments.

The evidence from the fungal spore analysis and from the hyphal debris analysis therefore suggests that the deposits at Locations B (SWPG), C (CRC) and H (SRC) are the result of recent disturbance by roots or by the activities of soil organisms. At all of these sites the hyphal fragments data suggests that both Oribitids and Lumbricids were acting to disturb the soil. However, there are other possibilities and these alternative explanations will be discussed below.

An alternative explanation for the fungal spore assemblage similarities beneath the external ramps is that the external ramps were later additions constructed at broadly the same time period or during similar environmental conditions.

The archaeological evidence suggests that the external ramps of the monuments at the Southern ring cairn and Balnuaran of Clava North-east are indeed slightly later additions to the main body of the cairns (Bradley forthcoming). However, the ramps at the South-west and Central cairns are considered to have been part of the original design of the monument, to buttress the outer kerb of monoliths (Piggott 1956, Bradley forthcoming).

There is no archaeological or environmental evidence that the ramps were much later additions to the cairns. The Southern ring cairn

dates to nearly a thousand years after the construction of the North-east passage grave, and it is highly improbable given the evidence from both the archaeological excavations and pollen analysis that the ramps were added to the Clava type cairns at the time of construction of the Southern ring cairn.

The second problem relates to the environmental conditions at the sampling locations. Palynologically speaking, Locations B (SWPG), C (CRC) and D (CRC) appear to have been constructed against similar vegetation backgrounds. Conversely, those from Locations G (SRC) and H (SRC) also have similar pollen records to each other but these are different to those at the Clava type cairns. This suggests that the Clava type cairns were constructed in one set of environments together, and the Southern ring cairn was constructed in a different set of environmental conditions.

Pollen evidence for intra monument environmental variation is only available for the samples from Balnuaran of Clava Central and Balnuaran of Clava South. The evidence of the soil pollen analysis shows similar pollen assemblages at Location D (CRC) the sample from beneath the core of the cairn, and that at Location C (CRC) beneath the external ramp (and also Location B (SWPG)), those from the Southern ring cairn (Location G beneath the core of the cairn and Location H beneath the external ramp) are consistent with each other whilst showing considerable variation from those at the Central Cairn, (and South-west cairn). The similarities of the pollen spectra within each individual monument supports the archaeological argument for unitary construction of the cairns. It is ,however, noteworthy that although the pollen spectra are broadly similar within the monuments the outer samples from beneath the rubble ramp appear to be more disturbed and less well preserved than those more securely sealed beneath the bulk of the monument cairn.

There is slight evidence from the soil micromorphology to suggest differing treatments of the soil at Balnuaran of Clava Central, which may account for the differences in fungal spore assemblages between Locations C (external ramp) and D (cairn core). However, there is no evidence that the soils at Balnuaran of Clava South where similar variation between Location G (cairn core) and Location H (external ramp) occurs for different soil or ground preparation. It is peculiar that the assemblages from the cores of the ring cairns, the ramps of the ring cairns and passage

graves and the unbioturbated deposits of the podsols have all tended to group together (especially in the Cluster analysis). This suggests that some as yet undiscovered environmental variation that may be related to human activity is linking the sampling locations. Further work on the taxonomy and taphonomy of fungal spores in soils may help to understand this problem.

Taken together the archaeological and palynological evidence suggests that the similarities in fungal spore spectra between the samples from the external ramps is not the result of either chronological or environmental similarities at the time of their construction.

The similarities in the recovered assemblages between both the ramp locations on one hand and some of the cairn locations on the other hand argues against this being the result of fungal spore heterogeneity or some stochastic process. The correspondences between the fungal spore assemblages at Locations B (SWPG), C (CRC), and H (SRC) suggests a consistent set of environmental parameters. Strong similarities in the fungal spore assemblages between both Locations A (SWPG) and E (NEPG) may also be noted in this regard.

Although there are several possible explanations for the similarities in the fungal spore assemblages between Locations B (SWPG), Locations C (CRC) and H (SRC) the most probable is that these are the result of post depositional disturbance of the deposits by roots and other biological activity during a period of similar post construction environmental conditions at the Cairns. This post depositional disturbance may in part explain the better levels of pollen preservation and pollen stratigraphy at Location D (CRC) compared to Location C (CRC). The significance of this later disturbance to the deposit for the pollen analysis will be discussed below.

Group 2: Unbioturbated samples from the North-east (Location E) and South-west passage graves (Location A)

The samples from Location A (SWPG) and E (NEPG) show a continuum of variation on the first principal component of the principal components analysis that is linked to the presence of small dark fungal spores such as ASM037, ASM035 and *incertae cedis* types IC008 and IC009. Samples from these two locations also formed discrete related groups in

the Cluster analysis. The similarities between the fungal spore assemblages of these two locations is tentatively interpreted as representing the effects of local burning. Fungal spore types ASM037 and ASM038 have been located by Clarke (1994) in samples from Balbridie associated with carbonized grain, and burning. At both Locations A (SWPG) and E (NEPG) burning is indicated both by the soil micromorphological analysis (Simpson and Davidson 1997), the microcharcoal analysis (Gale 1997) and at Location A by the presence of abundant burnt Coryloid pollen grains. Also, at both Location A (SWPG) and E (NEPG) the samples have not been bioturbated and so the fungal spore assemblage reflects the local environment at the time of deposition.

Further, both deposits are acid podsols with no evidence for earthworm activity or later biological disturbance e.g. no unpigmented hyphal fragments were located in these deposits. The fungal spore assemblage may also in part be related to acid podsolic soils. It may in fact represent the more durable elements of such an assemblage as many of the identified spore types are thick walled spores up to 5 % of which are either broken or corroded (Fig. 5. 12 and 5.35). In this case these microfossils (e.g. fungal spore types ASM037, ASM038, ASM040 etc.) may be better preserved in the deposit in a similar way to fern spores which are often better preserved in certain soil pollen sequences than pollen grains (Waterbolk 1958, Dimbleby 1985).

Group 3: Bioturbated deposits from the Central ring cairn (Location D) and the Southern ring cairn (Location G)

Samples from Location D (CRC) and G (SRC) both grouped together in the Cluster analysis and are all negatively loaded for the second principal component of the Principal Component Analysis. Closer analysis, however, suggests that while there are superficial similarities there are some differences also. Both locations are dominated by pollen (pollen forms between 60-90 % of the microfossil assemblage at both locations (Figs 5.28 and 5.40) unlike the other locations previously discussed. The assemblages are dominated by fungal spore types ASI039, Aggregate and Phomoid with the *incertae cedis* fossil IC008 also important. There are also some significant differences in the assemblages e.g. the presence of fungal spore type MOI013 at Location G, and its absence at Location D

and the absence of Brown carbonized material at Location G to name but two.

These two fungal spore assemblages are broadly similar and possibly represent a type of fungal spore spectra associated with bioturbation of podsolic horizons. There are differences between the two locations ,however, that may relate to the differing kinds of vegetation present at the sampling locations prior to burial. One difference is between LPfAZ CRC D1, where rises in the frequency of fungal spore types ASM001, ASM035, broken and corroded spores and decline in fungal spore type DII005 are not seen at Location G (SRC).

The spore assemblages at Location D (CRC) and G (SRC) are both from bioturbated soils beneath ring cairns. At the present time it is difficult to interpret their similarities except in relation to their context. Balnuaran of Clava Central and Balnuaran of Clava South where these samples originate from are, according to the excavator's interpretation and archaeological thinking (Bradley forthcoming, Barclay 1990, Henshall 1963.), widely separated in time. Their pollen assemblages and palynodebris assemblages are also dissimilar with more open grassy conditions indicated at Balnuaran of Clava South, whilst at Balnuaran of Clava Central a mixed grassy heath is indicated. Though it is tempting to relate the patterning in the fungal spore spectra to soil type, such a clear cut interpretation needs more data on the ecological affinities of fungal spores.

Interpretation

The samples examined from Balnuaran of Clava have been classed into three groups on the basis of similarities in their fungal spore assemblages. These groups are thought to relate to differences in the taphonomy and palaeoecology of the deposits. On the basis of the taphonomy of the deposits it is possible to simplify this classification to two groups. Those samples with evidence of post depositional biological activity (Locations B (SWPG), C (CRC), G (SRC)) and those which appear to have been sealed from biological activity since burial (Locations A (SWPG), D (CRC), E (NEPG) and G(SRC)).

The first group from Locations A (SWPG), D (CRC), E (NEPG)

and G(SRC) appear to contain undisturbed palynofacies assemblages which relate to the period of construction of the monuments. These assemblages can therefore be interpreted as representative of past environmental conditions at the monuments.

The second group Locations B (SWPG), C (CRC), G (SRC) are interpreted as having undergone at least one and possibly more periods of disturbance, probably as a result of later biological activity (root penetration, is thought to be the dominant mechanism). This disturbance has not greatly affected the observed pollen assemblage but appears to have greatly affected the fungal spore assemblage. Many of the spores observed in these samples appear to be conidial forms, produced by mitosis from *in-situ* hyphae (Griffin 1972, Ellis and Ellis 1988). The presence of unpigmented hyphae suggests that this process of disturbance is continuing up to the present day.

If we consider the context of the two groups of samples both would ordinarily be well sealed having been recovered from under between 0.3-1 m of overburden in the form of large boulders, and all sampling locations being derived from beneath large, greater than 0.5 m diameter boulders. Despite this some samples show signs of recent biological disturbance (altered fungal spore assemblages, unpigmented hyphae). The difference between the ramp samples and those from the core or central chambers of the cairns is the degree of burial. For Locations A (SWPG), D (CRC), E (NEPG) and G (SRC) these samples were sealed not only vertically but also horizontally by large kerbstones set below the level of the ground surface. It appears therefore that the main disturbance was derived from lateral penetration of the deposits by biological activity.

The conclusion that lateral disturbance of apparently sealed deposits is occurring is important not just for the use of fungal spores in archaeopalynology but also other disciplines concerned with soil analysis and the management of archaeological sites. This conclusion is ,however, only preliminary and based on a small number of sampling locations. More work on this matter may help to resolve the ecological basis of the observed fungal and palynofacies distributions. This result and that from Meldon Hills (Chapter 4) suggests that fungal spores and palynofacies analysis may have an important role for the understanding of soil processes, particularly when coupled with soil micromorphology for archaeologi-

cal research.

Having proposed different taphonomic histories for the deposits at the different sampling locations we now need to consider what effect, if any, taphonomic processes may have had on the soil pollen assemblages. To this end the following discussion concentrates on the evidence from the external ramps (Locations B (SWPG), C (CRC) and H (SRC)) and the samples from the cores of the ring cairns (Locations D (CRC) and G (SRC)). After consideration of these two groups a discussion of the taphonomy of the passage graves will follow (Location A (SWPG) and Location E (NEPG).

The prime question is did the proposed biological disturbance result in the movement of pollen within the soil and disturbance of any pollen stratigraphy that may have been present in the soil. This discussion is perforce based on monuments where pollen assemblages of presumed similar date are found in the same monument. This limits the discussion to the two ring cairns. Of those from the South-west passage grave, Location B is thought to relate to the period of construction of the Clava type monuments at the beginning of the second millennium BC, whilst Location A relates to reuse of the chamber at the end of the second millennium BC. There was only a single sampling from the core of the North-east cairn, and consequently no sample from beneath the ramp for comparison purposes.

An interpretation of the taphonomy of the deposits at Balnuaran of Clava Central

The first point to make about this discussion of soil pollen taphonomy is that without the combined use of palynofacies analysis and soil micromorphology it is doubtful if such a comprehensive discussion of taphonomy could be made. Soil pollen whilst an excellent research tool can when combined with the evidence from microfossil analysis provide more in-depth analysis of taphonomic processes.

If we take each monument, in turn, beginning with Balnuaran of Clava Central before considering Balnuaran of Clava South, it is possible to see some differences in the pollen spectra between sampling locations C and D. Before we can discuss the pollen spectra, however, we need to consider any biases that may have resulted due to differences in the

sub-sampling. Samples from Location C are from 10 mm intervals whilst the majority from Location D are at 5 mm intervals this may have had the effect of smoothing the curves of the major taxa at Location C.

Despite this, (and remember that we consider Location D to be undisturbed and Location C to have been subject to later biological disturbance) the pollen sequences at these two locations are remarkably similar in broad terms, an earlier phase of dominance by Poaceae and Coryloid changes with increases in both *Calluna vulgaris* and Poaceae in the topmost samples at both Locations (Figs. 5.21 and 5.26).

The most significant differences occur in the degree of pollen preservation at the two locations. At Location D levels of indeterminate pollen are below 10 % for the topmost samples whilst at Location C they are well above 10%, also at Location D the sum of well preserved pollen is in excess of 70 % at the top of the sequence whilst at Location C well preserved pollen is less than 30% throughout. Similar significant differences in all measures of preservation may be seen between the topmost samples at both sampling locations (Figs. 5.24 and 5.29)

An analysis of the pollen preservation data from Balnuaran of Clava Central suggests that the deposit at Location C has a less well preserved pollen assemblage than that at Location D. The significant difference in pollen preservation between the two locations may possibly be attributed to their different taphonomic histories. Although both deposits are described by the soil micromorphologists as being bioturbated, the pollen preservation results suggest that the proposed ongoing bioturbation at Location C has reduced pollen preservation. Values of deteriorated pollen, and percentages of indeterminate pollen are all higher at Location C whilst pollen concentration values are lower.

Pollen spectra and stratigraphy at Location D (CRC)

Later biological disturbance at Balnuaran of Clava Central appears to have led to a change in the fungal spore spectra and a decrease in pollen preservation particularly at Location C. Has this later disturbance also introduced new pollen taxa or otherwise disturbed the pollen stratigraphic record? In particular is the rise in *Calluna vulgaris* pollen the result of later biological activity or does it represent a change in vegeta-

tion cover before the monument was built.

At the Central cairn there is a change in the pollen spectra of the top samples with increases in the amount of *Calluna vulgaris* (and other taxa e.g. *Pinus* pollen). Three possible hypotheses for this change are considered: 1) it reflects a genuine change in the vegetation at the site prior to burial;, 2) it is the result of later downwards perculation of *Calluna vulgaris* pollen after the monuments were constructed (there is good evidence from Kennedy's report in the 1930's that heather and whin had colonized the monuments (Barclay 1990)); 3) that *Calluna vulgaris* was brought to the site as part of a pre-existing structure or for some other reason, prior to the monuments construction. To understand this question we must consider other avenues of evidence relating to the taphonomy of the deposit.

The discussion will be based primarily on evidence from Location D because that is the best sealed location with the least evidence for later disturbance.

If we consider Location D there is good evidence that large earthworms capable of moving pollen (Dimbleby 1985, Aaby 1983, Andersen 1984, Tipping *et al.* 1997) were not present in the topmost samples of the deposit from both the hyphal (Fig. 5.30) and the soil micromorphological analysis where mammilate excremental features (typical of larger earthworms) are rare in the upper layers of the deposit (Simpson and Davidson 1997). This suggests that the *Calluna vulgaris* pollen was not introduced into the soil by later earthworm activity. As earthworms and other soil fauna are the dominant method by which pollen is incorporated into soil (Andersen 1984, Aaby 1983, Tipping *et al* . 1997), this suggests that the *Calluna vulgaris* and other pollen is *in -situ* and not a later addition. It is also noteworthy that increases in *Calluna vulgaris* pollen did not occur at the Southern ring cairn, which lends support to this hypothesis. Further, at the North-east passage grave, several *Calluna vulgaris* pollen grains were identified in the topmost samples probably as a result of downward perculation of later pollen, however, the low numbers (*c.* 4 grains) suggests that perculation is not a major contributor to buried soil pollen assemblages (*cf.* Aaby 1983, Andersen 1984).

Further evidence for the *in-situ* presence of *Calluna vulgaris* at

the Central cairn is the presence of charcoal of this taxa in the deposits (Kaminski 1996). It therefore appears probable that *Calluna vulgaris* was present at Location D (CRC) prior to the construction of the monument, and probably derived from locally growing heather rather than being introduced as part of a later construction (this issue will be dealt with more fully below in the interpretation section).

The pollen and charcoal evidence both therefore suggest that *Calluna vulgaris* was present at Location D (CRC) prior to the construction of the cairn. Also the hyphal analysis and soil micromorphological analysis all indicate that large earthworm and invertebrate activity capable of soil mixing were not active in the upper layers of the soil at this location (see above and Simpson & Davidson 1997), and, further the palynofacies data suggests that the deposits at D were not subsequently disturbed. Taken together these disparate lines of evidence suggest that at least the upper parts of the pollen spectra at Location D is a record of vegetation prior to the construction of the Central ring cairn.

It must ,however, be remembered that the charcoal from this site (all fragments of hazel and birch) produced a range of dates from the sixth millennium BC to the second millennium BC (see above). Thus, it is still possible that the *Calluna vulgaris* charcoal and pollen are derived from later activity but parsinomy favours a model based on their prior presence. Dating of the *Calluna vulgaris* fragments would help to solve both the issue of the origin of the *Calluna vulgaris* pollen and the dating of the monument itself.

The above interpretation presumes that the pollen spectra at Location D relates to pre-monument activity. The obvious similarities between the pollen spectra between C and D suggests that Location C is also a result of pre-monument activity. This despite the suggested post-depositional disturbance to the fungal spectra. The effect of post depositional disturbance appears to have been to reduce pollen concentration and preservation in the deposit and to blur the pollen stratigraphy, without significantly affecting the relative proportions of the pollen spectra. If this conclusion is correct it maybe possible to extend it to the other sampling locations and consider their pollen spectra to be equally free of later intrusive pollen.

Balnuaran of Clava South

At Balnuaran of Clava South the situation is less clear cut than that at Balnuaran of Clava Central. Here, overall pollen preservation is much poorer than at Balnuaran of Clava Central (Figs. 5.41 and 5.46), but it is possible to suggest that overall pollen concentration values are higher and pollen preservation is overall better at Location G in the core of the cairn than Location H from the ramp. In particular, the structure of the data points to increasing pollen deterioration at depth at Location G whilst at Location H the picture is more confused with less correlation between depth and pollen deterioration.

The above discussion of pollen preservation suggests that levels of pollen preservation are lower in the deposits beneath the external ramps than in the cores of the cairns at the Southern ring cairn.

At Balnuaran of Clava South there appears to exist a similar situation to that at the Balnuaran of Clava Central. If we assume a similar set of arguments then it would appear that the pollen spectra of these deposits represent changes in vegetation immediately prior to the construction of the monument.

An interpretation of the taphonomy of the deposits at Location A Balnuaran of Clava South-west and Location E Balnuaran of Clava North -east

The remaining deposits to be considered are those from the core of the North-east passage grave, and the chamber of the South-west passage grave. In both of these deposits the soil micromorphology, palynofacies analysis and radiocarbon dating, all suggest that these are intact stratified deposits.

Balnuaran of Clava South -west

Firstly, if we examine the deposits from Location A from the chamber of the South-west passage grave. As discussed in the results section, this is a complex set of deposits which appear to represent a number of differing processes. The chamber of the South-west passage grave had (as discussed above) been excavated at least twice, once in 1828 and again in 1930-1 (Munro 1924, Barclay 1990). From these excavations the remains

of a cremation and two pots had been recovered (Henshall 1963). The pots associated with this cremation were identified by Piggott (1956), as being of late Bronze age date. A late Bronze age date for the cremation agrees very well with the radiocarbon dates from the chamber which are from the end of the second/ beginning of the first millennium BC. This cremation has been regarded by most authors as representing later reuse of the monument (Piggott in Henshall 1963, Bradley forthcoming).

The palynofacies analysis certainly suggested that this deposit was associated with a later burning. Levels of charcoal are higher in these samples than at any other location, in addition discrete levels with large numbers of burnt Coryloid pollen were identified (some of which were clumped together suggesting the burning of flowering Corylus) and the pollen spectra had few similarities to either Locations B (SWPG), or those from Balnuaran of Clava Central or Balnuaran of Clava North-east.

The soil pollen analysis at this location did not agree very well with that of the soil micromorphological report. To briefly, summarize Simpson and Davidson, identified this deposit as a *in-situ* buried soil into which later material was introduced (1997).

It may be suggested that LPfAZ SWPG1 correlates to Horizon 1 (see above Fig. 5.8, 5.9), the dominance of Poaceae pollen and Filicales in this zone, agrees with the suggestion of open grassy conditions made in the soil micromorphological report (Simpson and Davidson 1997). Horizon 2 would in this interpretation equate to the sample at the base of the sequence 45-50 mm which has clay coatings associated with cultivated soils and which appear to have formed before any major burning event. This sample has a depleted pollen spectra compared to the samples above it, and may therefore represent a truncated E horizon, as suggested by Simpson and Davidson (1997). Horizon 3 would therefore equate to the bulk of the samples from SWPG2 (20-45 mm). It is in these samples that charcoal concentrations are highest and that frequencies of burnt Coryloid pollen are greatest. Horizons 1 and 2 are therefore according the soil micromorphological study *in-situ* buried soil deposits (the equivalent of LPfAZ 1 and sample 45-50 mm) with the bulk of LPfAZ 2 equivalent to Horizon 3.

However, there are findings which conflict with this interpreta-

tion. In particular, the majority of burnt bone fragments were found in the top 20 mm and are therefore associated with Horizon 1. This would tend to suggest that rather than an *in-situ* buried soil Horizon 1 actually comprises redeposited soil associated with the later cremation. Such an interpretation is more consistent with the results of the radiocarbon dating from the chamber. Similarly, the pollen spectra from LPFAZ 1 has great similarities to those from the Southern Ring cairn which are of a similar date. Further, the pollen spectra and charcoal levels at Location B has few similarities to that at Location A.

The taphonomic evidence from Location A and B suggests that these two deposits accumulated in very different ways. The pollen assemblage at Location A results from the truncation of a *in-situ* E horizon and the deposition of at least one or possibly two sets of soil associated with burning and cremation towards the end of the second millennium BC. by contrast Location B, appears to represent an *in-situ* buried soil profile probably of early second millennium BC date, from the similarities of its pollen spectra to those at the Central ring cairn. And similarities in the construction of the three guardianship monuments (Bradley forthcoming).

The final sequence to be considered is that from beneath the core of the North-east passage grave, Location E. From a consideration of both the context, radiocarbon dating, soil micromorphology and palynofacies analysis, it would appear that the taphonomy at this location is relatively straightforward given the complexity evident at the other Locations. This relatively straightforwardness stems from the wide degree of agreement between all the lines of evidence which suggest that this podsol remained undisturbed after the monument was constructed and that therefore the palynofacies assemblage relates solely to the period prior to monument construction.

Despite this apparent transparency there is some evidence that the palynofacies assemblage has undergone differential preservation and that what remains are those pollen and fungal spore types least susceptible to destruction. For example pollen concentrations and numbers of taxa are low, which suggests that large amounts of pollen have been lost due to biological destruction (Waterbolk 1958, Havinga 1964). This is also the case for the fungal spore data set where there are large numbers of broken and corroded spores, and where the dominant spore taxa are those with

thick spore walls.

Recap

This discussion of taphonomy has attempted to demonstrate that the processes at work in a buried soil are complex and that they can lead to biased assemblages, either due to mixing of pollen spectra of different ages (probably the lower levels at Locations B (SWPG), C (CRC), D (CRC), G (CRC), and H (CRC) or because of differential pollen preservation (Location E (NEPG)). It has also demonstrated that a assemblage approach to fungal spores can work at least in this situation. Further, the demonstration that the fungal spore assemblages from locations B (SWPG), C (CRC) and H (SRC) have been contaminated by later fungal activity as a result of later biological disturbance is significant.

By firstly considering taphonomy it may be possible to at least partially unpick the various biases in the data to produce a limited interpretation. This is particularly so when the analyst can draw on materials from the archaeological context, soil micromorphology and macrofossil studies (in this case charcoal).

The interpretation of these sites could not be made as effectively without using a palynofacies approach. This approach has made several useful observations possible- the variation in pollen preservation between Locations C and D for instance. From an analysis of fungal spores and hyphal fragments it was possible to demonstrate the recent post depositional disturbance of soils beneath the external ramps, such disturbance may partly explain the high degree of bioturbation identified in these soils by the soil micromorphologists. Through the use of hyphal analysis it is possible to provide a further line of evidence to confirm the findings of soil micromorphology as to the nature and type of soil fauna present in a buried soil. In most cases there was excellent agreement between the results of the soil micromorphology and the hyphal analysis, suggesting that this technique should become a routine part of soil pollen work.

By providing a broad based description of the biological component of a sediment (a biofacies) it is possible to provide a type of independent control for soil micromorphological studies, not available solely from a consideration of pollen evidence. This was particularly seen at

Location D (CRC) where the palynofacies work suggests that the deposit is perhaps less bioturbated than indicated by the soil micromorphological analysis.

The soil micromorphological analysis and palynofacies analysis proved to be broadly in agreement in relation to the taphonomy of the deposits. The only serious disagreement being in relation to Location A, where differing interpretations are presented of the taphonomy and environmental interpretation of this deposit. If I have tended to favour the argument derived from the palynofacies analysis at Location A it is because it fits better with the known archaeological context of the deposits, the radiocarbon dates and the pollen analysis from other similarly dated locations. Overall, the analysis suggests that a combination of soil micromorphology and palynofacies analysis are powerful tools for the reconstruction of the taphonomy of buried soils, archaeological deposits and their environmental interpretation.

Palaeoenvironmental interpretation

In the following sub-section the palynofacies analysis, together with the subsequent discussion of taphonomy are used to provide individual accounts of the palaeoenvironment for each sampling location. This is followed by a discussion of phasing at the monuments following the excavator's (Richard Bradley) preferred interpretation. There then follows a integrated description of the proposed phases of environmental change at the monuments prior to their construction. As a general note the large quantities of Coryloid pollen found in this and the other analyses from the cairns are interpreted as deriving from *Corylus* as this is a prolific pollen producer and given the position of the sites, the contribution of *Myrica gale* to the pollen sum is liable to be slight. This position is supported by the charcoal evidence which suggests that *Corylus* was a major contributor to the charcoal recovered from all the sampling locations studied (Kaminski 1996).

Balnuaran of Clava South west (Clava type passage grave)

Location A Introduction

As discussed above, during preparation of the palynofacies

samples for analysis a considerable number of small fragments of burnt bone were located in the upper levels of this deposit. This, and the discovery of large numbers of burned *Corylus* grains in the samples, questioned the interpretation of this deposit as a buried soil horizon.

The evidence of burnt pollen grains, a fungal spore spectra containing taxa such as *Gelinaspora* spp., burnt bone fragments and large amounts of charcoal suggested that it was in fact a part of a cremation deposit, introduced into the chamber at a later date as part of the monuments reuse. Such later reuse of burial monuments is not uncommon, and an example is the nearby ring cairn at Raigmore where repeated episodes of re-use may be demonstrated (Simpson 1996, *cf.* Barclay 1992). The radiocarbon dates from this cairn, confirmed the result of the pollen analysis, as they demonstrated that the deposit dated to the early part of the first millennium BC. The radiocarbon dating suggests that the two LPfAZ present in this deposit are indistinguishable by radiocarbon dating and are therefore chronologically closely related.

Zone SWPG 1 (20-50 mm)

This zone appears to comprise a mixture of redeposited cremation deposits overlying a truncated E horizon as discussed in the taphonomy section above. The pollen and charcoal assemblage is dominated by *Corylus.* Much of this *Corylus* pollen had a pattern of degradation consist with being burned and was found in distinct bunches of between 2 and 12 grains (Figs. 5.9 and Appendix 5 Figs. 11.2-11.5). This indicates that the cremation occurred in the early spring when *Corylus* is in flower.

The pollen content of this zone, therefore, has been biased by human activities that have led to the dominance of *Corylus*. The pollen within this zone does not, therefore, broadly reflect that of the vegetation and is unsuitable for detailed palaeoecological reconstruction. There are, however, some noteworthy points to be made about the pollen spectra at this location. There is an almost continuous presence within the samples of Poaceae grains compatible with Andersens group two, probably *Hordeum* and two Poaceae grains from group three possibly *Avena* or *Triticum* (Andersen 1978). The presence of these grains suggests that cereal cultivation was either occurring in the soil redeposited with the cremation (as indicated by the soil micromorphological analysis), or they became

incorporated in the deposit during the cremation. A further interesting point is that *Pinus* is almost continuously present in this deposit, unlike the other locations sampled where it is relatively rare.

In this set of samples 36 different form taxa of spores, and other non-fossil palynomorphs were identified (Table 5.18). Within this zone two of the fungal spore types closely resemble microfossils identified by Clarke (1994) (her type number in brackets); ASM037, ASM038 (ASI068), MOI013 (MOI004). Of these ASM037 (ASI068) occurs in archaeological contexts within a burnt Neolithic grain store (Clarke 1994), but its ecological affinity is currently unknown. MOI013 (MOI004) is a cosmopolitan type associated with grassland/cereals and ruminants. The presence of *Gelinaspora* spp. is also consistent with burning.

Zone SWPG A2 (0-20 mm)

The palynofacies assemblage in this zone has also been affected by anthropogenic activities, the presence of calcined bone fragments in these samples suggests that pollen and fungal spores from a number of different environments may have been mixed.

Of the 36 types of fungal spore identified, six were attributable to named genera. The identified types by analogy with their occurrence in other studies indicate that these spores originated in a range of environments. The presence of abundant *Sordariaceae* species particularly type ASM029 (*Sporomiella* type (Ahmed and Cain 1972, Davis 1987) in the top four samples (0-20 mm) with those of ASM003 (*Tripterospora* type van Geel *et al.* 1983, Lundquist 1972), ASM010 *Podospora* type Kuhry 1985) and ASP001 (*Gelinaspora* type van Geel 1978, van Geel *et al.* 1988, Kuhry 1985 and Clarke 1994) suggest that dung and/or rotting vegetation may have been mixed into the deposit. The presence of ASP001 (*Gelinaspora* type van Geel 1978, van Geel *et al.* 1981, Kuhry 1985 and Clark 1994) which may be fimicolous, herbicolous or carbonicolous, is consistent with the other evidence for burning. Van Geel interpreted the presence of *Gelinaspora* type spores at Engbertsdijkveen as being the result of burning during a dry phase of the bog(van Geel, *et al.* 1981). The remaining identifiable spore type belongs to the Endogonaceae which are a large group of soil fungi of a cosmopolitan nature (van Geel 1978, Clarke 1994, Hawksworth *et al.* 1995).

The fungal spore spectra within this zone suggests the admixture of dung/ rotting vegetation, burnt material or soil containing these materials, into the deposit. The pollen spectra is dominated by Poaceae, *Filicales* and *Polypodium vulgare*. Minor pollen taxa include *Calluna vulgaris* and *Betula*. The herbaceous spectra is dominated by Asteraceae lactucoideae, Asteraceae undiff., *Galium*, type, Caryophyllaceae and Chenopodiaceae, the presence of these taxa and several *Hordeum* type pollen grains suggests that dung or cereal refuse may have become incorporated into the deposit, prior to the sealing of the monument. The pollen spectra in this zone suggests that it originated from a fairly open environment in which grassland and cereal cultivation are indicated. The pollen

AWH Type	Van Geel Type	C. Clarke type(1995)	Specific name
ASI041		ASI020	Endogonaceae
ASM003	T.169(1983)	ASI054	c.f. Tripterospora
ASM004	T.55 (1978)		c.f. Chaetomium/lophitrica type
ASM006	T465 (1989)		
ASM010	T.369		c.f.Podospora
ASM029			c.f.Sporomiella (Davis 1987)
ASM037		ASI068	
ASM038		ASI068	
ASD005	T.44 (1979)		
ASP001	T.1(1978)	ASP001	c.f.Gelinaspora

Table 5. 18 Table of Comparitive fungal spore types for Location A

and fungal spore spectra is dissimilar to that from Location B beneath the external ramp, but the pollen spectra has many similarities to that from Locations G and H from a similar time period.

Location B

The sequence can be sub-divided into two portions: a basal sample which has a higher level of *Corylus* pollen, and the top three samples (0-30 mm). The soil does not appear to have undergone any major physical disturbance, and although there are a limited set of samples the absence of sharp changes in the major taxa and the hyphal analysis suggests that some blurring or mixing of the pollen spectra by bioturbation

may have occurred. As discussed above it is a strong possibility given the presence of clear hyphal fragments, and the similarity of the fungal spore assemblage to those from Locations C (CRC), and H (SRC) that the fungal spore spectra does not represent environmental conditions at the sampling site prior to the construction of the monument. Few identifiable microfossils were present in the samples but the known taxa are identified in Table 5.19

Soil pollen profiles are complex, due to the possibility of mixing and the poorly understood mechanisms that lead to the formation of the profile (Aaby 1983, Andersen 1984, Dimbleby 1985). As discussed in the taphonomy section above this soil has been bioturbated by both soil micro fauna such as Oribitei and larger organisms such as earthworms. This has led to a mixing or blurring of the pollen spectra which greatly reduces the reliability of the following interpretation.

At the base (sample 40 - 50 mm) the assemblage is dominated by Poaceae, with few trees, but a high representation of *Corylus* pollen. This suggests either open conditions with some *Corylus* scrub or mixing of an earlier *Corylus* dominated assemblage with later open conditions. The presence of a cereal grain (anl D>8 um diameter type, grain, probably *Hordeum* was encountered (Andersen 1970)) suggests that the sampling location was close to an area of arable agriculture.

The topmost samples (0 -30 mm) indicate open surroundings

Sample depth(mm)	NAP/AP	AP+C/TP-S
10	7.58	23.03
20	7.39	32.67
30	11.85	25.52
50	13	42.36

Table 5.20 NAP/AP and AP+C/TP ratios from Location B

(Table 5.20), there is a decline in the frequency of *Corylus* and increases in the values of taxa indicative of a open conditions such as Poaceae and of herbs associated with pasture/cultivation such as *Plantago lanceolata,* Ranunculaceae and Caryophyllaceae. The proportions of *Betula* and *Alnus* remain constantly under 10% in these levels. There is an increase in the

amount of *Calluna vulgaris* and Ericales in sample 0-10 mm, which probably indicates an expansion of heathland in the vicinity of the sampling site. The increase in *Calluna vulgaris* is probably a response to increasing podsolisation and soil nutrient depletion. A similar rise in *Calluna vulgaris* was also observed at Locations C and D (below).

Nearby cultivation is indicated by grass pollen which fits Andersen's criteria for inclusion in the *Hordeum* type (Andersen 1970) and weeds of agriculture such as *Hornungia* type (a group of weedy crucifers associated with agriculture (Behre 1981, 1986). There is no evidence from the soil micromorphological analysis for *in-situ* cereal production at this sampling location but given the likelihood of post depositional bioturbation of this deposit this is perhaps not surprising. The soils study has concluded that the general level of stoniness, and impoverished nature of these soils, would not have favoured arable agriculture. The pollen evi-

Fossil type	Van Geel type	C.Clarke type(1995)	Specific type
ASM029			Sporomiella type(Davis 1986)
ASM004	T.55(1978)		Chaetomium/Lophitricia type
ASM007	T.465 (1989)		
ASM037		ASI068	
ASM038		ASI068	
MOI013		MOI004	
PHOMOID		Phomoid	
TORULOID FRAGMENT		Toruloid fragment	

Table 5.19 Table of Comparitive fungal spore types for Location B

dence does not support *in-situ* cereal cultivation either. Although cereal pollen is poorly dispersed in the environment, the frequency of cereal pollen in these samples are too low for *in-situ* cereal production (Hall

1989). They are however consistent with nearby cereal cultivation, the levels of cereal pollen are comparable to figures from areas adjacent to modern cereal fields (Hall 1989, Vuorela 1972).

The pollen spectra from the topmost sample at location B and those from locations C and D, all show a coincident rise in *Calluna vulgaris* pollen and also a rise in *Pinus* at locations B and D. Whilst not conclusive it is evidence that a similar set of environmental changes occurred at each monument prior to their construction.

Balnuaran of Clava Central (Clava type ring cairn)

Location C

As discussed above this deposit has been bioturbated and care is therefore needed in its interpretation. Despite this, it is possible to identify a shift in vegetation from open *Corylus/Poaceae* pasture, to more acidic grassy heath with increasing amounts of *Calluna vulgaris*.

The distinctive feature of this sequence are the high values of *Plantain* undiff. *Galium* type and *Primula veris* type. *Primula veris* type includes *P. eliator, P. veris and P. vulgaris,* and while no differentiation was possible within this group the presence of other weeds such as Asteraceae lactucoideae, Asteraceae undiff., *Plantago lanceolata* and *Plantain* undiff., suggests that well established open grassy conditions were present at Location C. The percentage values of *Corylus* pollen and the AP+C and AP/NAP ratio (Table 5.21) are noteworthy and suggest as at Location B either the presence of nearby *Corylus* woodland or scrub or that pollen from an older pre-clearance *Corylus* scrub has been mixed into the profile (Table 5.21).

Depth (mm)	NAP/AP	AP+C/TP
10	13.36	37.04
20	11.03	45.11
30	6.94	40.93
40	7.43	42.24
50	5.91	46.27

Table 5.21 NAP/AP and AP+C/TP ratios from Location C

The rise in *Calluna vulgaris* values in sample 0-10 mm is similar to that at Location B (SWPG) and suggests the expansion of heathland within the surroundings of the monument site either through human activities such as woodland removal, burning or loss of soil nutrients leading to increasing acidification (Moore 1988).

Many fungal spores were identified at this location, though few

Type	Van Geels	C.Clarke type (1995)	Specific name
ASD005	T.44 (1978)	ASD008	
ASI003	V.Gt.181	ASI012	
ASI010		ASI004, ASI014??	
ASI040		ASI049	
ASI041		ASI020	Endogonaceae
ASM001		ASI003	
ASM006	T.465		
ASM037		ASI068	
ASM038		ASI068	
MOI009		MOD001/MOD002?	
MOI013		MOI004	
MOI016		MOI014, MOI012	
ASM003	T.169	ASI054	c.f. Tripterospora

Table 5.22 Table of Comparitive fungal spore types for Location C

of them were identifiable to a particular biological taxon (Table 5.22). The presence of unpigmented hyphae and the similarity of the fungal spore assemblage to that at Locations B and H has led to the inference that this fungal spore assemblage may represent later intrusive fungal activity.

Location D

Zone CRC D1 (60-100 mm)

As discussed above the hyphal analysis, pollen preservation data and soil micromorphology all suggest that the topmost samples of this sequence are reasonably well stratified. This zone probably represents a mixture of pollen from the surface and lower down the sequence.

Although individual taxa show some variation within the profile, the overall pattern is broadly similar, being dominated by *Corylus* and Poaceae with high frequencies of *Betula* pollen. At the base of the sequence in samples 60-100 mm the pollen spectra and the values of AP+C/TP above 50% suggests the presence of open secondary (?) woodland at the site or a nearby woodland edge (Table 5.23). This woodland was dominated by *Corylus* and *Betula*. The presence of nearby woodland is particularly suggested by the presence of occasional grains of *Hedera helix* in samples 70-80 and 90-100 mm. Open conditions are, however indicated by pollen of *Plantago* spp. and *Primula veris* type whilst disturbed ground is suggested by the presence of cereal pollen and *Artemesia* pollen. The presence of taxa indicative of open and disturbed ground is probably the result of pollen mixing by earthworms or other invertebrates, down the profile.

LPfAZ CRCD2 (25-60 mm)

In this zone there are a number of fluctuations in the major taxa in particular *Corylus* and Poaceae. Also in this zone there is the beginning of continuous rise in brown carbonized plant material, coupled with low levels of fungal hyphae. It may be that this is evidence of a period of disturbance within the soil profile. Possibly there was a period of clearance, perhaps represented by sample 55-60 mm. At this level there is an expansion in the percentage of herb pollen recorded, and a decline in the percentage of *Corylus* and *Betula* pollen. There are a number of *Hordeum* type pollen grains in samples 45-50 mm and 55-60 mm. This increase in the level of herb pollen may be due to a number of causes, clearly small in scale and short in duration. This LpfAZ is similar in pollen content to the basal samples at Location C and also to those at Location B.

CRC D3 (0-25 mm)

As discussed in the taphonomy section it appears probable that this LPfAZ represents a reasonably stratified "snapshot" of vegetation change prior to the construction of the cairn. The top of the sequence (0-25 mm) represents a more open environment than the previous zone with a decline in the percentage of *Corylus* pollen and a reciprocal increase in *Calluna vulgaris* to *c.*18% of TLP while Poaceae is relatively constant until

sample 0-5 mm where it increases to 35% of TLP. The increase in Poaceae pollen suggests that after clearance by burning the site was left open and colonized by grassland prior to the construction of the monument.

The presence of a small number of macrofossils of charcoaled *Calluna vulgaris* and the pollen evidence suggests that *Calluna vulgaris* was growing at the central ring cairn prior to the monuments construction (Kaminski 1996). The increase of *Calluna vulgaris* is thought to represent the local replacement of a *Corylus* /grassland association by a grassland/ heather community in the vicinity of the sampling location. The soil micromorphological data indicates that ongoing autogenic changes, rather than human activity, lead to soil impoverishment, acidification and podsolisation (Simpson and Davidson 1997). These soil changes encouraged the development of *Calluna vulgaris* and appear to have occurred at both the Central ring cairn and the South-west Passage Grave.

There is a decline during CRC D3 in the amount of *Primula veris* type and *Plantago* spp. and a considerable increase in the amount of cereal pollen present within the zone. Along with the cereals, one grain of *Centaurea cyanus* (Cornflower) was also found in the topmost samples. The presence of a single grain of *Centaurea cyanus* is interesting. In general this taxa is associated with later medieval arable agriculture, and finds from the Neolithic and Bronze age are comparatively rare (Godwin 1956, Jones 1988). Finds of *Centaurea cyanus* are known from Danish pollen spectra from approximately this period, where they are associated with cereal cultivation (Andersen 1988). Other pollen types indicative of open conditions include *Artemisia* and *Scuttelaria* type (Behre 1986, 1981, Jones 1988).

The presence of a number of arable indicators in LPfAZ CRC D3, suggests local arable agriculture, as at Location B (SWPG). The pollen evidence and the soil micromorphological evidence is not however consistent with *in-situ* cereal cultivation, and probably derives from nearby cereal agriculture.

In general few types of fungal spore were located at this sampling site in contrast to Location C, and only two types were attributable to species or genus (Table 5.24). Of these the frequency of types ASM029 (*Sporomiella* type (Ahmed and Cain 1972 and Davis 1988) and ASM004 (*Chaetomium/Lophitricia* type van Geel 1978, Clarke 1994) are high in sam-

Depth (mm)	NAP/AP	AP+C/TP
5	4.7	41.25
10	4.54	41.33
15	4.5	41.98
20	5.29	43.67
25	7.86	42.66
35	5.07	48.86
40	5.15	48.85
45	4.52	56.21
50	4.05	49.33
55	5.65	57.12
60	6.31	42.91
70	5.54	51.05
80	4.84	54.36
90	5.53	50.64
100	3.6	55.13

Table 5.23 Location D NAP/AP and AP+C/TP ratios

ple 0-5 mm, these types are indicative of dung and cellulose decay, and may indicate human activity in the vicinity of the monument prior to its construction. A cluster of artefacts was found under this cairn further reinforcing the impression of human activity (Bradley forthcoming). It is possible that a temporary structure was present at the monument prior to its construction and the lithic scatter, fungal spore assemblage, cereals and arable weeds may reflect human activity in the vicinity of this structure. A house was found to underlay the Clava type ring cairn at Raigmore (Simpson 1996) and elements of domestic artefacts such as saddle querns were found at the ring cairn at Newton of Petty (Bradley forthcoming). It is a possibility that temporary domestic activity has affected the pollen and fungal spore content of the topmost sample at Location D.

Because of the small sampling interval in these samples (5 mm) it was possible to closely examine changes in the pollen and spore spectra prior to the ring cairns construction. The increase in charcoal frequency in

sample 0-5 mm, and Poaceae pollen, suggests that the hazel, grass and heather scrub, was burned off and replaced by grassland and it is perhaps during this phase that a structure of some kind was erected.

As at Location B, there is a increase in the frequency of *Pinus* pollen in the surface sample to 7%. This is unlikely to be the result of

TYPE	Van Geel type	C.Clarke type(1995)	Specific name
ASI010		ASI004, ASI014	
ASM001		ASI003	
ASM004	T.55(1978)	ASD001	Chaetomium/Lophitricia
ASM029			Sporomiella type
ASD005	T.44 1979		

Table 5.24 Table of Comparitive fungal spore types for Location D

opening of the vegetation increasing the regional component of the pollen spectra, as other regional taxa such as *Alnus*, and *Betula* remain constant. It may therefore reflect the expansion of *Pinus* as a component of the regional pollen rain at *c.* 2000 BC. Fine resolution pollen analysis at Rannoch Moor (south-west Highlands and LochStrathey north-east Scotland indicates a expansion of *Pinus* at *c.* 2000 BC (Lowe 1993).

Balnuaran of Clava North east (Clava type passage grave)

The sequence from Location E has little evidence for bioturbation. It therefore appears to represent a intact record of vegetation changes at the site prior to monument construction. However, caution must exercised as the sequence is the worst preserved of those analyzed as part of this study. It is possible that the high levels of pollen deterioration indicated has altered the frequencies and types of taxa preserved in the deposit. Research by Havinga (Havinga 1964) on differential pollen preservation suggests that in this case the dominant pollen taxa Poaceae and *Corylus* would be expected to be degraded at similar rates. This suggests that the relative proportions of these taxa are unaffected by deterioration. It is however probable that taxa susceptible to deterioration, especially tricol-

Depth (mm)	NAP/AP	AP+C/TP
10	11.14	53.3
20	23.71	73.1
30	17.84	33.1
35	9.07	53.45
40	29.79	47.85
50	18.98	62.4
70	9.58	73
90	24.64	63.1

Table 5.25 Location E NAP/AP and AP+C/TP ratios

pate types are less well preserved than at Locations C and D for example.

The pollen spectra below the turf line 35-90 mm suggests the presence of local secondary woodland dominated by *Corylus* with relatively high AP+C/TP (Table 5.25) values. This woodland is disturbed at sample 30-35 mm and there is an increase in values of Poaceae type, Rubiaceae, *Plantago* spp.and Asteraceae undiff.

The distribution of *Plantago* spp.either side of this sample perhaps indicates some mixing of the pollen assemblages during disturbance either associated with the construction of the monument or by soil fauna. Above the turf line we have three samples that contain high percentages of Coryloid pollen and this is consistent with an interpretation of redeposited material. The evidence suggests that the area was cleared by burning of *Corylus* dominated woodland/scrub prior to monument construction but that there was sufficient delay to allow the development of a open grassy conditions at the sampling site.

AWH type	Van Geel types	C.Clarke types(1995)	Specific name
ASI041		ASI020	Endogonaceae
ASM037		ASI068	
ASM038		ASI068	

Table 5.26 Table of Comparitive fungal spore types for Location E

The fungal spore spectrum at Location E contained one taxa identifiable to a known genus, and has some similarities with that from Location A at the South-west cairn (Table 5.26). This may reflect the effects of burning or the apparently poor conditions for the preservation of both pollen and fungal spore assemblages.

Balnuaran of Clava South (Ring cairn)

Location G Interpretation

This short sequence appears to have been constructed in a area free of woodland. The low values of NAP:AP reinforce this view, (Table 5.27) though the frequency of *Alnus* pollen (*c.*10%) suggests that this tree may have formed some woodland in the vicinity of the sampling site perhaps along the banks of the Nairn. The values of the AP+C/TP suggests the presence of local *Corylus* woodland or scrub (Table 5.27). However, the presence of cereals, *Plantago* spp. together with the values for Poaceae pollen suggest at least locally the presence of pasture, possibly interspersed with some arable activity, unless cereal pollen became incorporated into the deposit during its construction through some form of anthropogenic activity.

There are several indicators of disturbed ground within the sequence, pollen of plants such as *Artemisia* type, *Urtica* type point to the presence of disturbed ground within the vicinity of the sampling site. The only fungal spore type identifiable to genus at this sampling location was Endogenaceae, which is a cosmopolitan type associated with soil (Table 5.28).

Depth (mm)	NAP/AP	AP+C/TP
10	8.09	41.22
20	5.9	41.06
30	7.06	45.84
40	6.52	47.61

Table 5.27 Location G NAP/AP and AP+C/TP ratios

AWH type	Van Geel type	C. Clarke type (1995)	Specific name
ASI041		ASI041	Endogonaceae
ASM037		ASI068	x
MOI013		MOI004	x

Table 5.28 Table of Comparitive fungal spore types for Location G

Location H: Interpretation

This sequence suggests that at the time of monument construction the environment was that of an open clearing with some evidence for disturbed ground. High values of the AP+C/TP ratio (Table 5.29) suggest the presence of nearby *Corylus* scrub, however the presence of indicators of both open ground and of disturbed ground such as *Artemisia, Hordeum*

Depth (mm)	NAP/AP	AP+C/TP
10	6.98	40.37
20	5.25	45.42
30	9.1	35.32
40	7	35.14

Table 5.29 Location H NAP/AP and AP+C/TP ratios

type and abundant Poaceae suggests both arable and pastoral activity either at or in the immediate area of the sampling location.

As discussed above the similarities in fungal spore assemblage between this site and those at Locations B (SWPG) and C (CRC) suggests that it derives from later biological disturbance. Few of the types identified at this location have known biological equivalents but those that are known are indicated in Table 5.30.

AWH Type	van Geel type	C. Clarke type (1995)	Specific name
ASI003	T181	ASI012	Mxyomycete?Lycoperden
ASI027		ASI037	Sordariaceae
ASI029			Inocybe
ASI030		ASI003	
ASI040		ASI049	
ASI041		ASI020	Endogenaceae
ASM001		ASI003	
ASM004	T.55		Chaetomium type
ASM006	T.465	ASI012?	
ASM007		ASI012?	
ASM010	T.368		Podospora type
ASM037		ASI068	
ASD005	T.44	ASD008	
ASP001	T.1	ASP001	c.f.Gelinaspora type
MOI013		MOI004	
MOI016		MOI016	

Table 5.30 Table of Comparitive fungal spore types for Location H

Dating

Before discussing an overall interpretation of the sites, it is first necessary to discuss the phasing of the monuments and the probability of the various pollen sequences overlapping temporally.

This discussion is largely dependent on that of the excavator which is as yet unpublished (Bradley forthcoming). I am perforce working from as yet unpublished materials. This is a hindrance but the aim of the following discussion is to state the excavator's data and to consider if this fits with the available pollen and radiocarbon data.

The radiocarbon dates that related to the various sampling locations were outlined above. These are only some of the radiocarbon dates from the excavations at Balnuaran of Clava and a complete list is contained in Appendix 9.

If we first examine the North-east passage grave, the dates from the buried surface at this location are internally consistent with four dates spanning the interval 3475 ± 45 to 3595 ±50 uncal. BP (AA-25231-AA-24234). A further date of 5535 ± 55 uncal. BP (AA-25230) was also obtained from beneath the core of the cairn but this was residual charcoal of Mesolithic date. A series of dates were also obtained from the socket of a

kerbstone at the entrance to the North-east passage grave. These dates illustrate the problem with much of the dating evidence from the Clava cairns; the three dates obtained were 2945±50, 3145±55 and 3600±50 uncal. BP (AA-25235-AA-25237.

From the North-east passage grave, which has the best primary dating evidence, we have a cluster of four dates at *c.*3500 uncal. BP from the core of the cairn, a second cluster of two dates from the socket of a kerb stone dating to *c.* 3000 uncal. BP and two outliers one at 3600 uncal. BP from the kerbstone socket and one from the core of the cairn dating to *c.* 5500 uncal. BP. The outlier from the kerbstone agrees well with those from the core of the cairn. The evidence from the North-east passage grave suggests that it was constructed around *c.*3500 uncal. BP or the start of the second millennium cal. BC. The later charcoal from the socket of the kerbstone, would on this reading be intrusive, as a result of some kind of later human activity which disturbed this part of the monument. The report on the work of Kennedy at Balnuaran of Clava suggests that the kerbstones at the North-east cairn had to be levered back into place, such activity may have introduced later charcoal into the sockets of the kerbs (Barclay 1990)

The other apparently securely dated contexts on the site are those from the chamber at the South-west passage grave, and the Southern ring cairn. The dates from the chamber of the South-west passage grave are all from the later part of the second millennium BC/ early first millennium BC. Four of the dates span an interval from 2740±55 uncal. BP to 2790±60 uncal. BP (AA-21251-AA-21254) with a slight outlier at 2855±70 uncal. BP. This dates the activity at the chamber fairly securely to the end of the second /beginning of the first millennium uncal. BC. A similar set of dates came from the Southern ring cairn, here of four dates submitted three grouped between 2680±45, 2745±45 and 2770±45 uncal. BP (AA-25226- AA-25228) with an outlier at 2420±45 uncal. BP. Assuming the first three dates are correct this suggests a period of construction at the end of the second/ beginning of the first millennium BC for the Southern ring cairn. This is broadly synchronous with the activity at the chamber of the South-west passage grave. The pollen analysis from these three locations were broadly similar also.

The above represents the relatively straight forward portion of

dating evidence from the excavations at Balnuaran of Clava. From this we can suggest four discrete phases of charcoal deposition. The first is from the Mesolithic and may given the absence of Mesolithic artefacts from the area of the site and the surrounding fields (Bradley forthcoming) represent natural burning event (s). The second relates to the period of construction of the North-east cairn at the beginning of the second millennium BC. The third to a period of later activity in the middle of the second millennium BC (from the socket of the kerbstone at the North-east passage grave. The final period of activity relates to the use of the chamber of the South-west passage grave, and the construction of the Southern ring cairn at the beginning of the first millennium BC.

The major dating difficulty lies with the Central ring cairn. Of six dates obtained from this monument none fall within the same 100 year interval. Of the dates from the core of the cairn itself none of these even fall within the same millennia. The earliest date from the cairn is 6410±80 uncal. BP, the middle date is 3605±75 uncal. BP and the last date is from 2990±70 BP (AA-21255-21257). The dates from activities around the cairn are equally spread out. Two dates were obtained from a first millennium AD cremation positioned between the external ramp and the outer stone circle, (AA-21258 and AA-21259) and a further date related to residual pine charcoal (6670±85 uncal. BP) from the socket of one of the uprights of the outer stone circle.

If we consider the dates from the chamber of the South-west passage grave to represent later reuse, then the program of dating and excavation has so far only managed to date securely the North-east passage grave and the Southern ring cairn. Presently, the Central ring cairn and the South-west passage grave can only be dated by reference to other monuments of a similar type (in this case the North-east passage grave and the ring cairns at Newton of Petty and Raigmore).

Taking the dates from the core of the Central ring cairn, one date is residual (6410±80 BP). Of the two remaining dates one (3605±75 uncal. BP, AA-21256) overlaps with the dates of the construction of the North-east passage grave and agrees with those from the primary levels at Newton of Petty (Bradley forthcoming) and an interpolated late third millennium BC date from Raigmore (Simpson 1996). The second (2990±70 uncal. BP, AA-21257) overlaps with those from the socket of kerbstone

from the North-east passage (2945±50 uncal. B and 3145±50, AA-25236-37).

Bradley (forthcoming) has favoured accepting the earlier of the dates as being representative of the true age of the monument. His arguments for an earlier date is that a early second millennium date would be consistent with those for the construction of the Clava type ring cairns at Raigmore, Newton of Petty and the North-east passage grave at Balnuaran. Bradley also goes on to consider the South-west passage grave as being constructed at the same time as the North-east passage grave. He considers this because they are "identical" to one another (Bradley forthcoming chapter 5 p.4).

His arguments for considering the three large cairns in the guardianship area to be constructed at broadly the same period are based on the results of the excavations rather than the radiocarbon dating. Briefly, they relate to the reuse of quarried slabs of sandstone in the base of the ramps of all three monuments. It is argued that this stone was not quarried deliberately for construction of the mounds rather that it formed part of a previously existing structure in the vicinity of where the cairns were ultimately constructed. Whatever the origins of the slabs, they were used in exactly the same way in all three monuments which may suggest that the cairns were constructed broadly synchronously. Further, elements in the layout and construction of the three cairns suggest that they were constructed at the same period. These are the use or reuse of cupmarked decoration, the almost identical construction of each passage grave, the use of a single axis of alignment for both passage graves, and the fact that two of the stone circle uprights of the ring cairn also fall on this axis.

A additional line of argument is available from the soil pollen analysis. The pollen and charcoal evidence (Kaminski 1996) from both the Central ring cairn and the external ramp at the South-west passage grave suggests that these monuments were constructed in broadly similar environments of open grassy heath with some hazel/ birch scrub. The soil pollen analysis at both cairns suggests that the increase in heath taxa (*Calluna vulgaris*) occurred before the monuments were constructed. Whilst not conclusive, it is a further element which links these two monuments. The development of heathland did not occur at the North-east cairn which suggests that some combination of temporal, spatial or taphonomic difference in the vegetation record has occurred.

The above is a summary of the arguments for considering the monuments to have been constructed broadly contemporaneously. This is the excavator's hypothesis. Whilst not without merit, the argument for simultaneous construction has several drawbacks. One of these is the presence of a putative earlier construction at the site of which no trace now remains, to supply the quarried slabs. This may be questioned on two counts. Firstly, outside of Orkney a tradition of building houses with quarried slabs is unknown in this part of mainland Scotland during the Later Neolithic and Early Bronze Age (Ashmore 1996). Secondly, all of the material for construction of the cairns derived from the bed of the nearby River Nairn, either in the form of rounded boulders or as quarried slabs. There appears to be no reason why slabs could not be quarried at the same time as boulders and cobbles were being gathered. However, despite these questions, at present and until further dating is carried out the hypothesis that the three main mounds were constructed simultaneously will be followed in the palaeoenvironmental reconstruction.

For the purposes of this discussion we need to consider the likely phases to which the palynofacies data relates. Examining the dates there are three or four possible phases to which the palynofacies evidence is likely to relate. The first of these relates to the residual Mesolithic dates from Scots Pine and hazel, the second to the beginning of the second millennium BC (five dates from the North-east passage grave and one from the Central ring cairn), the third to the middle of the second millennium BC (two dates from the North-east passage grave, one from the central ring cairn) and the fourth to the end of the second/ beginning of the first millennium BC (all of the dates from the chamber of the South-west passage grave and the Southern ring cairn).

A synthesis of the data suggests that the pollen analyses from the three Clava types cairns relates to a period prior to their construction at the end of the third millennium/ beginning of the second millennium BC. The pollen analysis from the Southern ring cairn and the chamber of the South-west passage grave therefore relates to a later phase at the beginning of the first millennium BC.

The dating of the Clava cairns attempted to take advantage of best archaeological practice (Bradley 1996) by using AMS dating techniques coupled with soil micromorphological analysis to determine the

"best" contexts for dating. The project used 23 AMS dates to date four monuments, in this it successfully dated the construction of two of the monuments (North-east passage grave and Southern ring cairn) and the later reuse of the chamber of the South-west passage grave. This methodology, however, initially failed to recognize the nature of the deposits in the chamber of the South-west passage grave (Simpson and Davidson unpublished data) and failed to obtain a set of consistent dates from the Central ring cairn.

Although it is becoming best practice to use soil micromorphological evidence to inform the selection of samples for radiocarbon dating (Bradley 1996), this writer believes that a better method would be to use soil pollen or palynofacies analysis in addition as a basis for selection. It was possible using a facies approach to identify three phases of burning activity before the monuments were sealed. Considering each case separately, the first of these was from beneath the body of the North-east passage grave. The pollen analysis showed that secondary woodland dominated by hazel had been burnt to make way for the construction of the cairn. Dating of five samples of hazel at this location produced a tight group of four dates from *c.* 3475-3595 uncal. BP, with a single residual outlier. A similar result also occurred at the South-west passage grave where again there was good evidence for a burning event dominated by hazel from the soil pollen analysis, five dates on hazel fragments produced a group of dates with four from 2740-2790 uncal. BP and a single outlier at 2855 uncal. BP.

The final site with good evidence for clearance by burning came from beneath the body of the Central ring cairn. However, at this location the soil pollen analysis indicated that the landscape prior to the monuments construction was open grassy heath in which hazel and birch were less important. At this site no *Calluna vulgaris* samples were submitted for dating. The samples that were submitted came from hazel and birch. As discussed above these dates failed to form a coherent group. It is this authors opinion that this was because they derived either from later intrusive activity or earlier burning events. To derive a reasonably accurate date from the Central ring cairn it would be necessary to date some *Calluna vulgaris* fragments. At the Southern ring cairn the lack of evidence for clearance by burning suggests that the spread of dates at this site pos-

sibly relate to the construction of the monument but may equally relate to a period of burning prior to this of which no record was preserved in the soil pollen sequence.

On the basis of the results from Clava cairns it may be strongly recommended that when it is planned to use AMS dating from buried soils, that soil pollen and where possible palynofacies analysis be carried out to assess whether the charcoal samples relate to a burning event immediately prior to the monuments construction, or are residual.

Palaeoenvironmental Synthesis

As discussed above, the excavator recognizes two main phases of construction activity at Balnuaran of Clava. The first phase sees the construction of the three Clava cairns in the guardianship area at the beginning of the second millennium BC. However, it must be born in mind that only one of the cairns (North-east passage grave) is presently firmly dated to this period. The construction of the South-west passage grave has no radiocarbon dates at all, whilst that at the Central ring cairn has two; the first relating to the beginning of the second millennium BC, the second to the middle of the second millennium BC. In such circumstances the following reconstruction should be regarded as tentative.

The second phase is more securely dated and relates to the reuse of the South-west passage grave and the construction of the Southern ring cairn at the beginning of the first millennium BC.

The following analyses may be divided into two groups, the first group comprises four sequences from primary deposits at the three Clava type cairns, and a second group of two sequences from primary contexts at the Southern ring cairn and a secondary sequence at Balnuaran of Clava South-west. This discussion will deal with each of these two groups in turn. The pollen data contains information, relating to local changes in vegetation prior to the construction of the monuments, and the type of economy practiced by the societies that built the monuments. These analyses are of local changes only and probably do not reflect wider changes in the landscape (Dimbleby 1985). It may be worth mentioning here that *Pinus* was a relatively rare pollen types in the analysis, despite the evidence from charcoal of its local presence during the seventh millen-

nium BC. With regard to *Pinus,* many fragments of brown carbonized material (Appendix 5 Fig. 9.6), were found at all locations except the Southern ring cairn. This material has not been positively identified but it looks like it may have derived from coniferous tracheids (Schweingruber 1990). The possibility that brown carbonized material derives from pine is an intriguing one which may provide opportunities for studying past pine distributions.

Analyses from primary contexts excavated beneath the Clava cairns at Balnuaran of Clava

Vegetation patterns at the start of the second millennium BC

To summarize, the sequences from primary contexts at the cairns within the guardianship area (Locations B, C, D, E) present a strikingly similar picture of open vegetation prior to the monuments construction.

The pattern of vegetation change is similar at the South-west passage grave and Central ring cairn and can be broken down into two or three phases. The type of vegetation varies slightly at all locations probably as a result of the mosaic nature of the vegetation and because of variations in pollen spectra that occurs as a result of soil processes. Phase one consists of the lower samples from Locations B, C, D and E. Phase two consists of LPfAZ CRC D1, sample 0-10 mm from Location B and sample 0-10 mm from Location C, this phase was not present at Location E. Phase three comprises samples 30-35 mm from Location E, sample 0-5 mm from Location D phase three was not recognized at Locations B and C because of their lower sampling resolutions.

Phase One

The area in which the monuments were constructed initially appears to have been open scrub/grassland, with *Corylus* and *Betula.* It appears that open conditions were better developed at the South-west passage grave during this phase, and more closed conditions were present at the Central and North-east cairns.

The *Corylus* component is difficult to quantify because when unshaded it is a prolific pollen producer (Johansen 1950, in, Andersen

1970). Values of *Corylus* do not however suggest closed canopy *Corylus* woodland, though they do indicate its presence locally. Values for *Corylus* are at their highest at the North-east cairn and at their lowest at the South west cairn. The Central ring cairn indicates intermediate conditions between these two locations.

During this earlier phase, arable cultivation, indicated by grains of cereal type pollen and weeds associated with disturbed ground, was practiced in the vicinity of both the South-west cairn and the Central ring cairn. The dominant land use however appears to have been pasture and probably gathering of *Corylus* nuts and other herbs, (Hazel shells have been recovered from the charcoal analysis (Kaminski 1997)). The duration of the cleared area is unknown elsewhere in eastern Scotland during the second millennium BC clearings last approximately 200-500 years e.g. at Braeroddach loch (Edwards 1979a, p.260). The mixed grass/hazel scrub suggests that the landscape was being manipulated to allow the growth of *Corylus* but retard forest regeneration. There are several means of achieving this, through periodic clearance of the regenerating *Betula/Corylus* scrub, either for arable agriculture or pasture, a system of bush fallow (Welinder 1983: p.47), or possibly the deliberate propagation of *Corylus* as a part of the agricultural system. There are indications of a small clearance episode at Location D during LPfAZ CRC D2 which suggests that periodic clearance was used to maintain open areas.

Closed broad leaved woodland was not local to any of the sampling sites, and the local nature of the diagrams provides little indication of woodland in the wider landscape at this time. The dominant tree species are *Betula* and *Alnus* with lesser amounts of *Quercus, Pinus, Tilia* and *Ulmus* identified. The presence of *Quercus* charcoal (Kaminski 1996) suggests that *Quercus* was a component of the vegetation or was brought some distance, or that the charcoal had been resident in the soil for some time. *Pinus, Tilia* and *Ulmus* pollen are very rare and are thought to be the result of long distance transport. *Alnus* and *Salix* pollen suggests the presence of these trees along the banks of the Nairn approximately 200 m to the west. At Location E it appears that secondary woodland dominated by *Corylus* was the main vegetation cover.

During this earlier phase, heathland appears to be absent at the sampling locations but the presence of heathland, and areas with impeded

drainage, are all indicated in the landscape by the pollen spectra.

All the samples from locations B, C, and D contain indications of either cereal type pollen or weeds of disturbed ground, such as *Artemisia, Urtica* and members of the Chenopodiaceae family. The presence of these arable indicators at the sampling locations indicate nearby cultivation. No cultivation indicators were identified at the North-east passage grave during this phase, and it appears that this area consisted of an area of denser *Corylus/ Betula* scrub.

Phase Two

The open conditions at the Central and South west cairns led to soil deterioration and loss of nutrients and the development of small areas of heathland in the vicinity of the monuments. The increased values of *Calluna vulgaris* pollen and the identification of carbonized *Calluna vulgaris* wood at the Central ring cairn indicates the local growth of heath. The more closed conditions at the North-east passage grave did not apparently encourage heath at this location. This phase of increase in *Calluna vul - garis* appears to have been the result of natural processes rather than human interference and may have been short lived (Simpson and Davidson 1997). *Calluna vulgaris* pollen does not attain values indicative of extensive heathland, rather the pollen spectra suggests a grass dominated heath at the sites of the Central ring cairn and South-west passage grave.

Phase Three

At the Central and North-east cairns clearance of respectively grassy heath and *Corylus* scrub/woodland occurred some time before the monument was constructed. This clearance was effected by burning, as the charcoal records suggest. The soil micromorphology suggests that this burning episode was not very intense. The cleared land was not immediately used for monument construction but was left to allow the growth of a grassy turf.

The topmost samples from Location D (CRC) are somewhat unusual; whilst there is good evidence for some local heathland, there is evidence for cereals of both barley type and wheat/oats type. In addition to these cereal grains, taxa not consistent with a heathland environment were also located in sample 0-5 mm, e.g. *Centaurea cyanus,* and

Cannabis/Humulus type. A possible explanation is that pollen and possibly soil from arable areas, or waste material was introduced into this deposit. The presence of lithics sealed beneath the monument along with the cereal pollen, and fungal spore types indicative of dung and cellulose decay is suggestive of local human activity, or possibly temporary settlement.

The monuments appear to have been constructed on the edge of a clearing whose centre was to the south west. Within this clearing *Corylus* grew but other trees such as *Betula* and *Quercus* were less important and their growth may have been retarded through deliberate management of the vegetation, possibly by grazing pressure. There is evidence for cereal cultivation in the vicinity of the monuments. This and the presence of grazing suggests a mixed economy with arable agriculture based on shifting horticulture, around a settlement site, rather than formal land division into permanent fields.

The pollen analysis though not excluding the possibility of some form of transhumant pastoralism as proposed by Philips (1994), suggests that the Clava cairns formed part of a stable farming economy in which both pasture and cereal cultivation were important. These findings would tend to support other evidence from Scotland summarized in Barclay (1997) that in the Later Neolithic subsistence economies were based on permanant settlements with a mixed farming economy.

In conclusion, if we assume contemporaneity of these deposits the vegetation record at these sites demonstrates the mosaic nature of past vegetation in a way that is beyond conventional pollen analysis using off site deposits such as lake or bog sediments. The vegetation patterns present suggest that current assumptions of a strict division between wildscape and landscape may mask the underlying ecological complexity of clearings and of the mechanisms of clearance. The reality may have been different, with vegetation managed at a much lower level leading to mosaics of better and less well managed land within cleared areas.

Vegetation analysis in the first millennium BC

Three sequences were recovered that dated to the first millennium BC. One was from the reuse of the chamber of the South-west passage grave, the other two are from the Southern ring cairn.

The two profiles from the Southern ring cairn cairn are similar to each other in that they are dominated by Poaceae pollen with low levels of tree and spore pollen. These locations indicate a more open environment than that present in the samples from the guardianship monuments with a reduction in the quantity of trees and shrubs. *Alnus* appears to have become more important but this may be misleading and probably represents a decrease in *Betula* and other trees rather than an expansion in *Alnus*. One interesting change is the decline in *Calluna vulgaris* values.

The decline in *Calluna vulgaris* suggests that the landscape in the vicinity of the cairns was being better managed to reduce heath and replace it with grass presumably for pasture.

The sequence from the chamber of the South-west passage grave is largely unhelpful for environmental reconstruction, as so much of it is related to the deposition of the cremated remains. The choice of flowering *Corylus* as a constituent of the cremation pyre indicates that the cremation occurred in the early spring (*Corylus* flowers in the present day in February-March). The topmost samples, may represent the ambient pollen rain prior to the sealing of the monument. If so, they present a similar pattern of vegetation to that seen in the Southern ring cairn.

The samples from the Southern ring cairn indicate more open conditions than those from the earlier phase. However, heathland taxa are less well represented at the sampling locations during this period. Cultivation is indicated close to the Southern ring cairn, but as with the other locations this appears to be adjacent to the sampling sites, rather than *in-situ*.

Conclusion

The aims of this analysis were several: to reconstruct the palaeoenvironment prior to the cairns construction; to examine the role of palynofacies analysis in the study of buried soil taphonomy; and to examine the use of palynofacies assemblages in the study of buried soils.

Palaeoenvironmental reconstruction

The majority of the palaeoenvironmental information at the sites examined derived from the pollen assemblages examined. From the

pollen reconstructions and archaeological phasing of the monuments a suggested interpretation of the past vegetation was proposed. Other elements of the palynofacies assemblage also contributed to an understanding of the past environments at the sites. In particular, the fungal hyphae and fungal spore data contributed to a greater understanding of the soil processes that affected the site than would have been available from pollen evidence alone. Several drawbacks to the use of fungal spore data were also identified.

In four of the assemblages examined there appeared to have been some form of post depositional disturbance which invalidated these assemblages for palaeoenvironmental reconstruction. The degree to which the NPF assemblages can contribute to palaeoenvironmental reconstruction is clearly dependent on whether secure taxonomic information for that spore type is available. Regrettably in this study only around 5% of the microfossils can be securely identified. The study of the fungal spore spectra of terrestrial as opposed to mire environments is in its infancy, but with more studies better environmental information should become available.

Where identifiable taxa were present, a number of microenvironmental variables were identified, most of which were associated with soil, the presence of dung, burning and cellulose decay. More work is required to widen the number of identifiable fossils, and this may prove to be very valuable for the analysis not just of archaeological but also conventional mire deposits. The presence of these spore types provided further evidence at locations A and E for burning and at Location D for some form of human activity possibly including burning, dung and rotting vegetation.

The analysis of soil palynofacies from the excavations at Balnuaran of Clava has produced some interesting results relating the vegetation history at the sites to the archaeology of the monuments. It has provided information on the construction of the monuments and the practices of the people who constructed them. The analysis although not authoritative is reasonably in agreement with the excavator's hypothesis that the Clava cairns were constructed in one phase and that the outer kerbs were part of the original design. This being the case, the three Clava cairns provide a transect in space across an area utilized for cultivation,

grazing and possibly occupation. The monument outside of the main area provides a glimpse of how the surrounding vegetation had changed a thousand years later.

The use of palynofacies analysis in the palaeoenvironmental study at Balnuaran of Clava has provided a greater degree description of the past environment at the site than would have been available by conventional pollen analysis.

Use of palynofacies assemblages in soil pollen analysis.

The integration of a number of palaeoecological techniques in the study at Clava cairns has demonstrated the effectiveness of the technique in providing additional taphonomic information relating to the buried soils that would otherwise not be available. The use of palynofacies assemblages was less effective in the reconstruction of palaeoenvironment present at the sampling locations, but this is largely due to the infancy of the subject, especially in regard to identification of dispersed fungal spores.

Taphonomy.

The use of fungal spore assemblage data, palynodebris analysis and fungal hyphal frequency analyses provided much information regarding the taphonomy of the deposits. The curious nature of the fungal spore assemblages was at least partially explained by the presence of clear hyphal fragments in the deposits from beneath the external ramps of the cairns. This has been interpreted as resulting from lateral disturbance of the deposit and the introduction of a later or possibly modern spore assemblage at the monuments. This hypothesis requires to be confirmed by further work.

However, if it is demonstrated that lateral disturbance of soil profiles on archaeological sites is occurring, then this has serious implications not just for soil pollen and palynofacies analysis, but also for soil micromorphology, radiocarbon dating and other archaeological disciplines reliant on the concept of sealed deposits. The implication of this is that observations from buried deposits may be the result of post depositional disturbance. This may be why there is a lesser degree of bioturbation in deposits from beneath the cairn which were sealed both laterally and ver-

tically, and those from the ramps which are only sealed vertically at the Clava cairns.

The use of hyphal frequency analysis at Balnuaran of Clava together with soil micromorphological analysis provided a further method for assessing the type of soil fauna present in the samples.

Soil pollen analysis

The soil pollen analyses at Balnuaran of Clava were conducted using the model of soil pollen incorporation put forward by Andersen (1979) and Aaby (1983) as discussed in Chapter 2. Broadly, speaking the results of this study tend to confirm Andersen's model of soil pollen incorporation. If we think of the bioturbated acid podsols, these have evidence for greatly increased pollen concentrations suggesting that surface pollen is being moved into the profile by invertebrates where the acid conditions lead to its preservation. As conditions become more acid the depth to which pollen is incorporated lessens and a pollen stratigraphy begins to develop. This is perhaps best seen at Location D where as heath plants increase, probably as a result of increasing acidification greater differentiation of the pollen stratigraphy occurs. In the podsol sequence at Location E pollen concentrations are lower, and the pollen stratigraphy is very clear though in these very acid deposits pollen destruction is greater, possibly because of longer residence times, and increased levels of oxidation (Dimbleby 1985). These results therefore support a model of soil pollen incorporation based on invertebrate activity (Aaby 1983, Andersen 1979) rather than perculation (Dimbleby 1961, 1962, 1985).

The results from this study indicate that soil pollen analysis is a valid method for recovering environmental information from buried soil surfaces and archaeological sediments. Indeed because it can be intimately related to the archaeological site in question soil pollen analysis offers many advantages to the archaeologist not available from conventional pollen analytical methods. Further, by using soil pollen analysis as part of an integrated methodology to select samples for radiocarbon dating some of the difficulties due to the long residence time of charcoal may be overcome. For example, if *Calluna vulgaris* charcoal had been selected for dating from the Central ring cairn, a more accurate date would have resulted, as this taxa formed part of the most recent vegetation at the site. From, the

pollen analysis it was clear that most of the taxa submitted for radiocarbon dating (hazel, pine, birch), had the potential to be residual or intrusive and indeed this proved to be the case. It is hoped to obtain dates from *Calluna vulgaris* fragments at the Central cairn to both date it and to demonstrate the efficacy of the methodology employed at Balnuaran of Clava.

The use of palynofacies analysis at Balnuaran of Clava has produced some interesting conclusions. Overall, the technique provided much additional information relating to both the taphonomy of the soil deposits and the environmental reconstructions of the sites. For example, where microfossils have come from identifiable groups they have helped to indicate a degree of human interference in the soils immediately prior to construction or closure of the monuments (Locations A, D). The hyphal analysis provided good correlations with that from the soil micromorphology. The analysis of fungal spore and *incertae cedis* microfossils suggests that post depositional disturbance has affected all samples not sealed both laterally and vertically. This disturbance has increased the degree of bioturbation of the deposits appears to have reduced the pollen concentration in the disturbed location and to have increased levels of pollen deterioration.

Further work on the identification of fungal spore types and their generation, transportation and deposition should help to develop palynofacies and fungal spore analysis to a level of sophistication similar to that of pollen analysis.

Chapter Six: Trowie Loch, Shetland

Introduction

This chapter reports on the palynofacies analysis of the basin deposits at Trowie Loch, which span the period from the ninth millennium BC to the middle of the second millennium BC. This research is part of the South Nesting Palaeolandscape project, an investigation of the Neolithic and Bronze age landscape of South Nesting Shetland. To place this study into context it is first necessary to consider the geographical background to the Shetland Islands and prior investigations of their archaeology and vegetation history. Which is followed by a short section which introduces the South Nesting Palaeolandscape study. The remainder of the chapter discusses the results, interpretations and conclusions of the palynofacies study. Please note that all BC dates are calibrated and all BP dates are uncalibrated (see Chapter 3 for details of calibration).

Physical, archaeological and vegetation history relevant to the study

The Shetland Islands

The group of islands collectively known as the Shetland Islands (Fig 6.1) are situated 44 km north of their nearest neighbours the Orkney Islands, 127 km north of the Scottish Mainland; Norway lies 292 km to the east. The largest island in the group is Mainland; other important islands are Yell, Unst and Fetlar. Most of the archipelago falls north of 60^{o} latitude.

The South Nesting peninsula is positioned approximately 20 km north of Lerwick on the east side of the Mainland. Trowie Loch (NGR HU 470 537) is a small, irregularly shaped brackish loch, set within a partially infilled basin, *c.* 300m in diameter at approximately 0m O.D. The loch is fed by a small stream that flows from the Loch of Benston, and is drained via a tidal inlet into the Vadill of Garth (Fig 6.1) (Appendix 5 Figs. 17.1-18.1). At the head of the loch a small salt marsh has developed, which may be of comparatively recent origin (see below). The pollen catchment is less than a square kilometre in area. The small catchment size of the basin should ensure that the pollen record is sensitive to nearby vegetation changes within the catchment (Jacobson and Bradshaw 1981, Birks 1986).

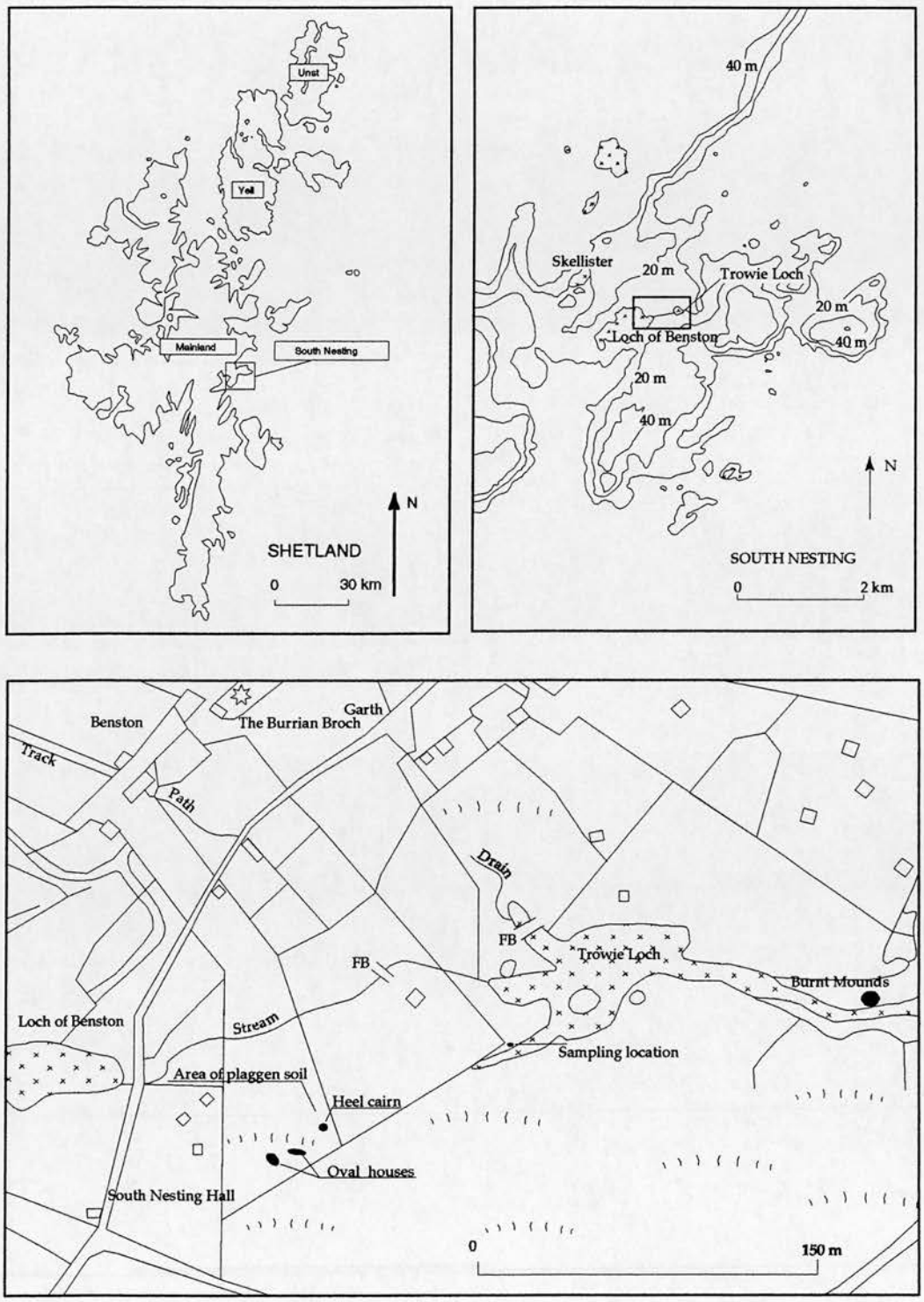


Fig. 6.1 Location map of Trowie Loch, South Nesting, Shetland, Scotland, showing pollen sampling location and excavated sites mentioned in the text.

Climate and Palaeoclimate

Maritime influences exert an ameliorating influence on the climate despite the islands' northerly latitude. The climate of Shetland is oceanic with cool summers and mild winters. Mean temperatures presently range from 3.05 °C in February to 12.01°C in July, and rain is frequent. A main feature of the climate is windiness with 236 hours of gale annually at Lerwick, nearly five times that of Kirkwall in Orkney (Berry and Johnston 1980), and a mean annual wind speed at Lerwick of 30 k.p.h. compared with 15 k.p.h. at Aberdeen (Spence 1979). Spence considers the lower limit of subarctic oceanic climate and vegetation to be around 200 m in more sheltered areas dropping to 100m in more exposed areas of Shetland (1979, p.14).

Palaeoclimate

This section attempts to set later discussions of the role of climate in both archaeological and vegetation change in context. The discussion is largely concerned with briefly summarizing present day approaches to palaeoclimate and to consider the sometimes conflicting results of differing proxy climate records. Detailed discussion is however postponed to later in the chapter.

For the non-specialist, discussions of climate are particularly difficult to evaluate. It is clear that there is a degree of disagreement as to the type and duration of climatic change during the Holocene (Briffa and Atkinson 1997, Edwards and Whittington 1996, Tipping 1994, Bennett *et al.* 1992, Kutzbach *et al.* 1993). The earlier scheme of Blytt and Sernander (in Godwin 1956) as developed by Godwin (1956), envisaged a dynamic Holocene with continuing changes in both temperature and wetness. This picture of a dynamic climate was further refined by Lamb (1977), who in an influential text set out a series of major climatic changes during the Holocene. Recent studies based largely on climatic modelling (Kutzbach and Guetter 1986, Kutzbach *et al.* 1993), have contrastingly tended to emphasize climatic stability during the Holocene with few significant changes after *c.* 9000 uncal BP.

The computer based modelling studies have been interpreted differently amongst palynologists and archaeologists. Bennett, using the models of Kutzbach, has suggested that " climatic changes induced by the Earth's orbital variations cannot by themselves account for the Holocene vegetation

changes seen at Dallican Water" and by inference Shetland in general (Bennett *et al.* 1992 p.263). This view of a largely static Holocene climate has yet to be taken into account by archaeologists' who continue to use the Lamb model of a changing climate (Turner (a) 1998, Dockrill and Simpson 1994). In order to assess these contrasting viewpoints it is necessary to examine albeit cursorily, the main themes of current thinking in palaeoclimatology.

The main issues that arise from palaeoclimatic studies are the effects that climate change may have had on both human and vegetation communities. There are two key periods for this discussion. The first is a postulated "climatic optimum" between *c.* 8000-6500 uncal. BP (Mayewski *et al.* 1996) during which it has been suggested by Tipping (1996) that heathland expanded. The second is the climatic downturn after 4000 uncal. BP but especially between *c.* 3000-2000 uncal. BP (Lamb 1977, Harding 1982, Burgess 1985, Briffa and Atkinson 1997, Turner 1998, Dockrill, Bond and O'Connor 1998, Butler 1998). This supposedly pronounced period of poor weather was traditionally thought to have led to the onset of blanket bog over much of Shetland and led to a decline and relocation of population during the middle and later bronze Age (Burgess 1985, 1989, Keith-Lucas 1986, Turner 1998, Fojut 1994). At the time of writing there is little agreement as to whether either of these two climatic events occurred.

An example of the lack of agreement is the argument for a climatic optimum from *c.* 8000-6500 uncal. BP. Mayewski (*et al.* 1996 p.78) argue, based on evidence from the Greenland ice core that a period of milder conditions coincided with the climatic optimum *c.* 8000-6500 uncal. BP. However, later in the same article, this is downgraded to a possible climatically optimal period with the statement *"if* (authors emphasis) the ice core record provides evidence for a prolonged period of drought or warming during the period 8000-6500 uncal. BP" (Mayewski *et al.* 1996 p.81). The paper thus appears to be both advocating and then tempering the possibility of a climatic optimum. A period of increased temperatures has been suggested by Tipping (1996) after *c.* 8000 uncal. BP based on micro-charcoal and pollen studies in the North of Scotland, though as yet this hypothesis has not been confirmed. In the absence of any detailed work on palaeoclimate in the Northern Isles the possibility of a prolonged warm phase *c.* 8000-6500 uncal. BP remains a largely untested hypothesis.

Assessments of a climatic downturn after *c.* 4000 uncal. BP appear

to be undergoing a degree of rehabilitation (Blackford 1993, Briffa and Atkinson 1997, Whittington and Edwards 1996). A recent survey by Briffa and Atkinson of a wide range of proxy sources suggests that "..this picture is fairly consistent with the early concepts of a warm dry sub-Boreal and cooler wetter Sub-Atlantic and especially the marked cool/wet transition between them at about 2500 uncal. BP" (Briffa and Atkinson 1997 p.103, see also Barber *et al.* 1994 and Blackford 1993). The proxy data sources from Britain discussed in Briffa and Atkinson (1997) tend to undermine climatic models of a largely stable climate discussed above. The nature of the climate shift after 4000 uncal. BP is however, unclear and may represent a number of differing climatic shifts affecting different areas across Northern Britain. Presently, caution is required in ascribing a climatic cause to the vegetation and archaeological changes witnessed after *c.* 4000 uncal. BP in the Northern Isles, because of the lack of palaeoclimatic research in the region.

The conflicting nature of the evidence and the multiplicity of techniques involved in palaeoclimatic research make it a difficult field for the non-specialist to obtain a clear view of the available data. The position in palaeoclimatology appears likely to remain a fluid one, as mathematical models are improved and tested against the available proxy data. The present situation for the Northern Isles is unsatisfactory with no really suitable proxy datasets to test the results of climate models or the data from the Greenland ice cores (Bunting 1994). The above discussion suggests that climate change during the Holocene may have been significant and sufficient to alter vegetation on Shetland but at present it is difficult to disentangle climate change from other causes such as human or autogenic changes.

Geology

The Mainland is formed from rocks of the Palaeozoic period. The geology comprises a complex suite of metamorphic, sedimentary and igneous rocks (Mykura 1976). The dominating trend of the rocks is N-S,which is reflected in the long N-S trending valleys of central mainland, where heather and blanket bog dominate on gneisses and schists. The heathland of central and northern Mainland is broken up by bands of limestone which with on account of their increased fertility, form noticeably greener areas amongst the heather (Scott and Palmer 1987).

The geology of the Trowie Loch basin (Fig. 6.2) is Pre-Cambrian in

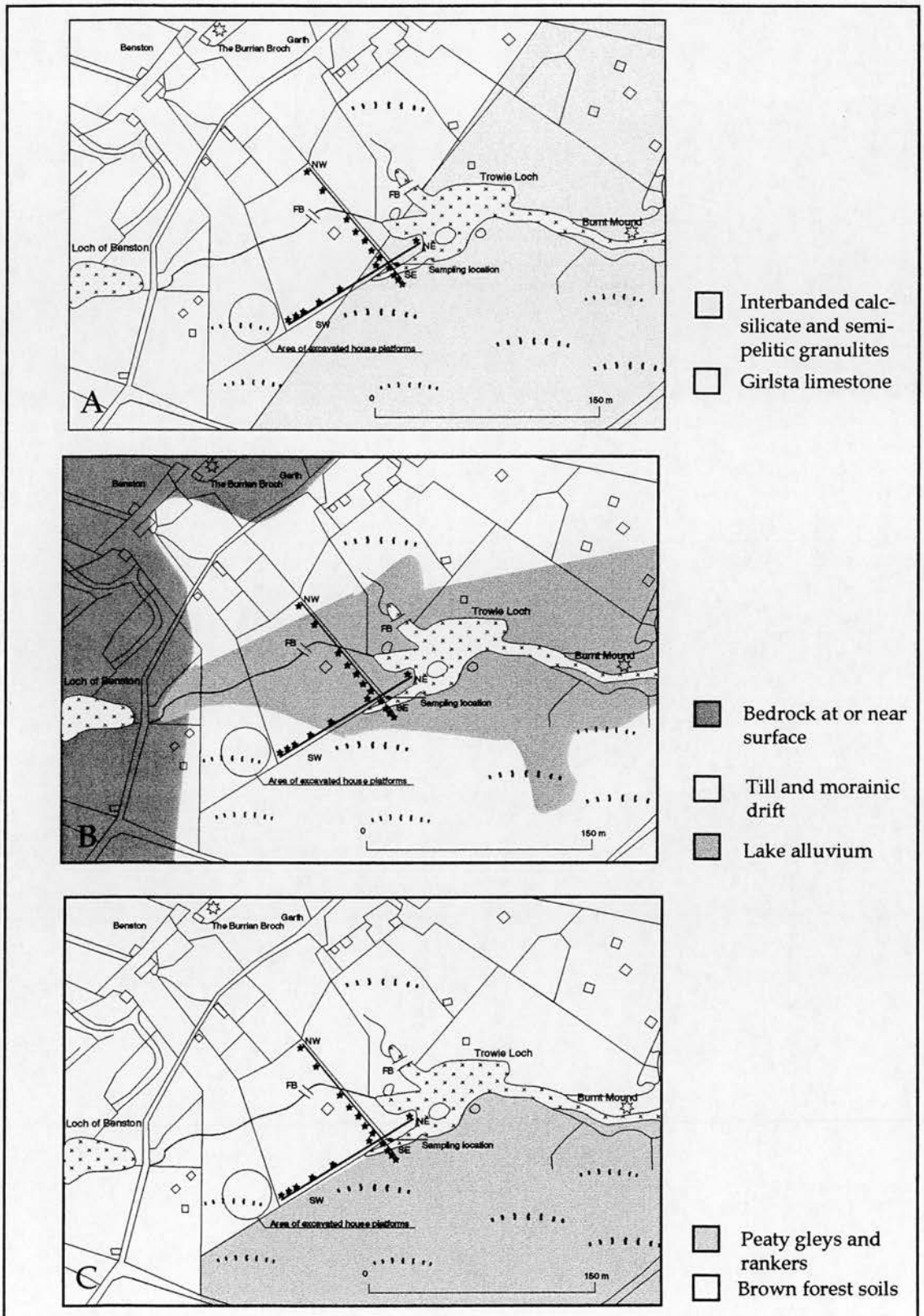


Fig 6.2 Maps of Solid geology A (after British Geological Survey 1981), drift geology B (after British Geological Survey 1981) and soils C (after Macaulay 1982)

age and comprises part of the Whiteness division (Mykura 1976), with flaggy psammites interleaved with hard crystalline metamorphic limestones (Fig 6.2 A). The bedrock is overlain by till, morainic drift, lake alluvium, basin peat and by poorly developed soils (Fig 6.2 B) (Britain 1981).

The most agriculturally productive soils on Shetland are brown soils and shell sand soils (Spence 1979). The brown soils are generally developed over limestone, serpentine and sandstone and are found in isolated bands principally in valleys such as Tingwall, Whiteness and the South Nesting peninsula on Mainland. Calcareous shell sands are found in the south of Mainland mainly around Sumburgh. The dominant covering of much of west, central and north Mainland is of blanket peat, relieved by areas of peaty podzols (Spence 1979).

The soils within the Trowie Loch basin are brown soils of the Deecastle series, with some peaty gleys and rankers to the north and west of Trowie Loch (Macaulay 1982) (Fig. 6.2C). These soils form the main agricultural land, and are used for both arable and pasture. To the south and south-east of Trowie Loch lie poor soils, of the Arkaig series; predominately peaty gleys, peaty podzols and peaty rankers, these occupy an extensive area of unimproved pasture developed over psammites (Macaulay 1982).

Sea level change

Trowie Loch is presently just above Mean High Water Springs, according to the latest O.S. map, but in reality sea water funnelled along the narrow Vadill of Garth does enter the loch intermittently. This has led to the loch becoming brackish. Relative sea-level change on Shetland has not been extensively studied (Firth and Smith 1993), however occasional findings such as those from Symbister harbour (Hoppe 1965) suggest that sea level has risen by approximately 9m since 5500 uncal. BP. Other evidence from Salt Ness (Flinn 1979, in Firth and Smith 1993) suggests that the rate of change subsequently slowed and that present day sea levels are only slightly above those of 4000 years ago.

There is evidence from several sites on Shetland that a possible tsunami event may have affected the Shetland coastline (Firth and Smith 1993). The coastal sites of Burragarth (Unst), and Garths Voe (Mainland) have produced evidence of a layer of sand and gravel intercalated with peat or lake sediments (Smith 1993a): at Burragarth peat below the sand and

gravel layer was dated to 7215±60 uncal. BP (no lab number quoted). Smith (1993a) has speculated that this sand layer is connected with the tsunami event known as the second Storegga slide which dates to approximately 7000 uncal. BP (Dawson, Long and Smith 1988). The second Storegga slide was an event of some magnitude, which affected the coastlines of both Norway and Scotland (Dawson, Long and Smith 1988, 1990).

Vegetation

Exposure, land use and soil are all important contributors to the distribution of vegetation on Mainland. The landscape especially in northern and central Mainland is largely of uninterrupted moorland developed over blanket peat or peaty podzols (Spence 1979). Moorland is dominated by the Ericaceae, especially *Calluna vulgaris* , with various sedges.

In South Nesting, the main area of moorland occurs a kilometre to the north of Trowie Loch on the acidic gneisses. Heathland is another important community which develops over drier better drained peaty soils with *Calluna vulgaris* and a number of grasses and sedges such as *Festuca viviparia* and *Nardus stricta.* Heathland is prevalent to the south of Trowie Loch in Gletness. Pasture is the dominant vegetation type within the agricultural areas, and this is true of much of South Nesting, with good quality pasture forming the dominant land use of the area to the north and west of Trowie Loch. Within South Nesting there are small arable plots with a three crop rotation of barley, potatoes, and kail.

Subsistence agriculture

The climate combined with the poor soils restricts the number and type of crops that may be grown productively on Shetland. During the eighteenth and nineteenth centuries the dominant crops were barley, kail, turnips and potatoes (Knox 1985, Fenton 1978). The growing season is short and presently sheep farming and fishing are important in the rural economy. Currently, the South Nesting peninsula has a mixed agricultural economy with both arable (potatoes, barley, cabbages) and the rearing of stock, principally sheep, but also horses and cattle.

Archaeological background

The main monument types and subsistence economy of Neolithic

and Bronze Age Shetland are described below(Fig. 6.3 illustrates the location of the major pollen and archaeological sites mentioned in the text). This section will focus on the vegetation, cultural and possible climatic changes relating to Mesolithic activity, the arrival of farming populations and the evidence for a hiatus in the Middle to Late Bronze Age.

Mesolithic

To date no archaeological evidence for a Mesolithic occupation of the Shetland Islands has been recovered (Edwards 1996). This absence is on one hand considered to be due to the remoteness of the Shetland and the difficulties of the sea passage, or conversely to be caused by the destruction of Mesolithic sites by sea level rise or by burial beneath peat (Edwards 1996). Some pollen analysts now consider that they have identified changes in the palynological record consistent with a Mesolithic presence on the Islands (Bennett *et al.* 1992, Edwards 1996), this evidence will be discussed further below.

It is worthwhile remembering that Shetland is a remote Island not visible from the Scottish Mainland. Even so, the failure to locate Mesolithic artefacts is somewhat surprising, as in a wider Scottish context, Armit notes " many sites around Scotland contain both Mesolithic and Neolithic cultural material" (Armit 1996 p.282). The failure to find a Mesolithic artefact in an archaeological context on both Orkney and Shetland, given that many Neolithic sites have been excavated over a considerable number of years, does not suggest a large Mesolithic presence (Ritchie 1990, Turner 1998). Whilst some form of Mesolithic activity on the Islands is possible, whether this took the form of permanent occupation or occasional temporary incursions is presently unknown.

Neolithic (3500-1800 BC)

The archaeological study of the Neolithic of Shetland may be divided into two parts; the first of these is the settlement record in the form of houses and field systems; the second is the record of ritual monuments such as burial mounds and standing stones. The settlement record has been better researched, with several excavated sites, most of which have been dated by radiocarbon. The record of ritual monuments is less well known (Henshall 1963, Turner 1998 (a)) and presently the dating of most of these monuments is by means of typological links with the excavated houses on

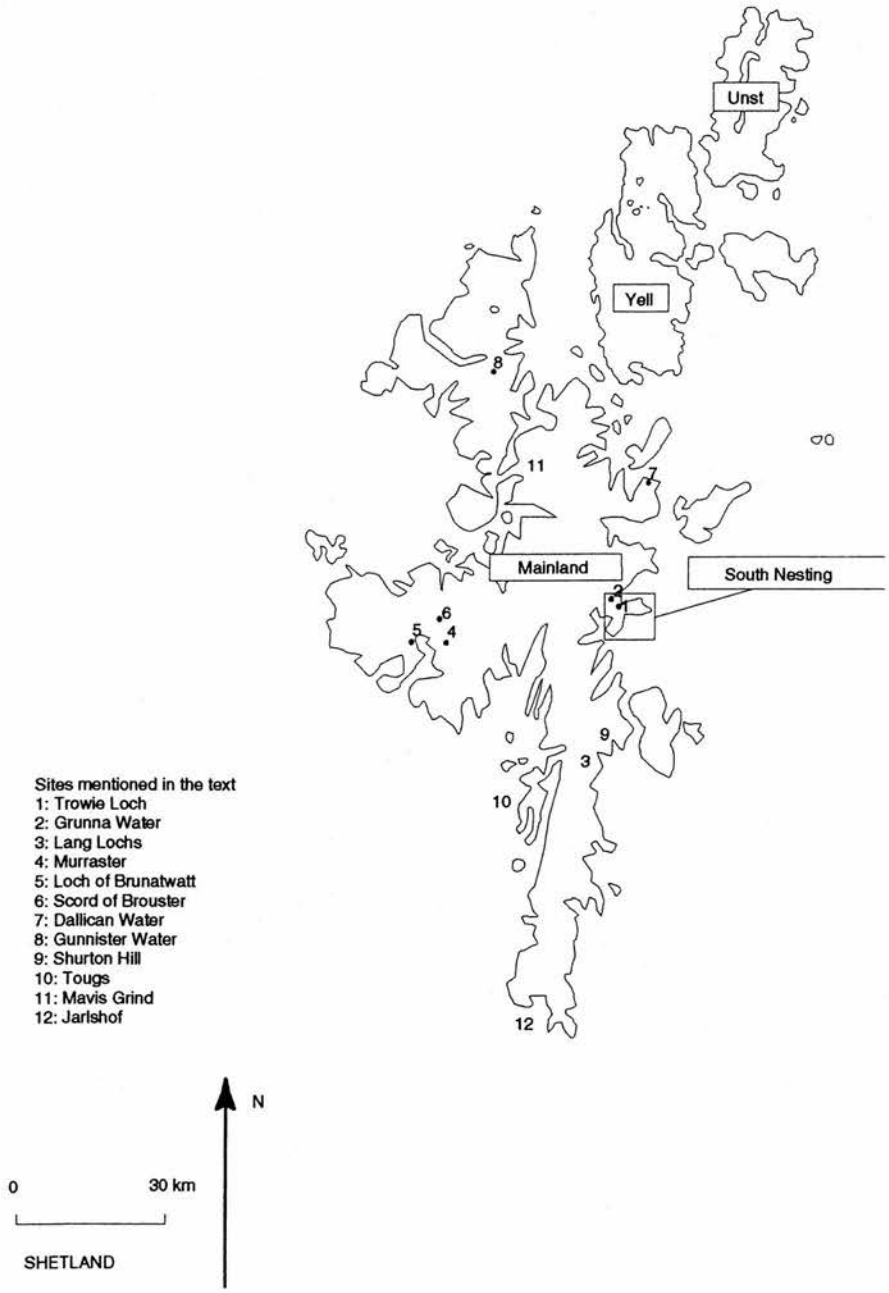


Fig. 6.3 Archaeological and palynological sites mentioned in the text.

Shetland and through similarities with burial monuments on Orkney and elsewhere (Turner 1998).

Presently, the earliest dated monument found on Shetland is the field dyke investigated by Whittington at Shurton Hill, near Lerwick (Whittington 1980). The radiocarbon date quoted by Whittington is "2800 uncal. bp" (UB2122) (Whittington 1980 p.35) which calibrates to approximately 3500 BC Pollen analysis indicated an open impoverished grass/heather community at the site at the time of its construction. Later, as the grass/heather balance changed and conditions became wetter, the dyke was overwhelmed by peat growth, which was attributed to the effects of muir burn and overgrazing coupled with climatic deterioration.

Calder was the first to systematically study the evidence of widespread prehistoric settlement and he conducted several surveys and excavations on the Shetland Islands (Calder 1955-6, 1962, 1963-64). The dominant type of house structure from the Neolithic through to the end of the Bronze Age/beginning of the Iron Age (and possibly during the Iron Age *cf.* Cracknell and Smith 1983, Fojut 1985) were small stone-built ovoid houses (Whittle *et al.* 1986). In two cases stone built oval houses have been found to overlie earlier timber built structures. At the Scord of Brouster an earlier timber house of the Neolithic period was found immediately to pre-date a later stone oval house (Whittle *et al.* 1986) and at Sumburgh airport a timber house of the Early Bronze Age was also found beneath a later stone house (Lamb 1985).

The earliest excavated example of an oval house is that of House 2 at Scord of Brouster, dated to 2590 ±65 bc (CAR-249) (cal. 3380-3030 BC), which correlates well with palynological dates for the onset of clearance at a number of pollen sites on Mainland. The three stone houses excavated at Scord of Brouster were produced markedly different dates from *c.* 3400 BC to *c.* 1600 BC, a period of nearly 1600 years. The available evidence suggests that each house was occupied for long periods with little structural change (Whittle *et al.* 1986 p.133). Oval house sites are often associated with field boundaries and clearance cairns e.g. Tougs (Hedges 1986) and South Nesting Hall, (Dockrill, J. Bond, and Connor 1998), as they were at Scord of Brouster.

The oval house appears to have formed the basic house type until the advent of round houses in the pre-Broch phase of the Iron Age. Over time the walls appear to have become thinner and the shape more rounded

but essentially similar structures to those at Scord of Brouster have been excavated at Ness of Gruting 2300-1950 cal. BC (BM-441) (Calder 1955-6 and Barcham 1981), Tougs 1596-915 cal. BC (Hedges 1986 p.12) and Mavis Grind (early iron Age) (Cracknell and Smith 1983). Other oval houses excavated at Jarlshof and Wiltrow were dated to the end of the Bronze Age and beginnings of the Iron Age respectively *c.* 7th/6th centuries BC (Hamilton 1956). Mention must also be made of the large house structure known as the Stanydale Temple from the West of Mainland. This structure is twice the size of a normal oval house and is thought to have had a specialized function possibly as a meeting house (Calder 1952, Turner 1998). The finds from the temple indicate a late Neolithic/Early Bronze Age date (Fojut 1994).

Several oval houses were previously known from South Nesting and several more were located during the archaeological survey, (Dockrill 1992). The oval house excavated at South Nesting Hall (Fig 6.1), has been linked on the basis of the artefact assemblage to the adjacent excavated heel cairn, and the nearby burnt mound at Vadill of Garth (Dockrill, Bond, and O' Connor 1998, Dockrill and Simpson 1994). This linkage remains, hypothetical, however as no radiocarbon dates are available for any of these sites. Radiocarbon dates from the anthropogenic soil associated with the oval house and its field system indicates a period of agricultural activity as denoted by ard marks at the base of the plaggen soil from 3620 ± 55 uncal. BP (SRR-5255) to 1630 ± 45 uncal. BP SRR-5254 (*c.* 2000 BC-400 AD). On the available evidence there is presently no independent date for the monuments excavated by the project.

Burial monuments

During the Neolithic a number of burial customs are known but due to a lack of radiometrically dated examples, it is very difficult to know if these represent chronological, status or cultural differences in the choice of rite. The only radiometrically dated example, a multiple cist burial from Sumburgh, is an atypical burial rite for the Islands, dated to *c.* 3200 cal. BC (Hedges and Parry 1980). Burial cairns are the most common funerary monument and are in three general forms (Henshall 1963). The dominant type is the Zetland group, followed by passage graves and a single example of a long cairn. The Zetland group has three sub-divisions: heel shaped cairns, square cairns and round cairns which may contain trefoil chambers, rectan-

gular chambers or cist. The chambers of the Zetland group may be reached by passages through the facade as at Pettigarths field, the side as at March cairn or the entrance may be blocked as at Vementry (Henshall 1963). These tomb types are broadly considered to be of Neolithic or Bronze Age date, based on the structural similarities between the facades at the Stanydale Temple and many of the heel shaped cairns. The value of curved facade's as a chronological indicator must be questioned however, given its long history of use at sites such as Sumburgh where heel shaped houses dating to the later Bronze Age are found (Lamb 1985, Turner 1998). At some point during the Bronze Age a switch to cremation and burial in a small cist under a cairn began (Fojut 1986).

A small heel cairn was excavated at South Nesting Hall *c.* 30m to the west of the oval house. The excavators report that the site had been robbed but that the remains of a cremation indicated its funerary nature. Similarities in the vessel form and fabric found in the cairn with the pottery found in the nearby house and the burnt mound have led the excavators to consider the three monuments (house, cairn and burnt mound) as part of a contemporary or near contemporary landscape (Dockrill, Bond and O'Connor 1998).

Bronze Age (c.1800-800 BC)

The main cultural changes that characterize the Bronze Age are the adoption of cremation as a burial rite, changes in ceramic form, and some stone tool types and the development of the burnt mound (Fojut 1994). It has also been postulated that climatic deterioration during the second millennium BC or the volcanic eruption of Hekla in 1159 BC led to a decline in population and the abandonment of agricultural land, with the development of heathland and blanket bog (Fojut 1994, Turner 1998 (a), Ritchie 1995, Øvrevik 1985 see also Burgess 1985, 1989).

During the Bronze Age a new form of monument, with a wide distribution in Northern Europe, is found in Shetland. These are the burnt mounds, and they are found throughout much of western and northern Europe from Ireland across to Scandinavia (Buckley 1990). Chronologically they fall into two distinct periods with examples from the Bronze and Iron Ages and again during the medieval period, particularly in Ireland (Buckley 1990). On Shetland they are generally considered to date from the Bronze

Age (Ritchie 1995, Fojut 1986, Dockrill Bond and O'Connor 1998).

The function of burnt mounds has recently been debated (Buckley 1990, Hodder and Barfield 1991). Hedges and subsequently Barber, have argued that the burnt mounds in the Northern Isles represent domestic settlement (Hedges 1977, Barber 1990). This argument in part rests on the presence of house like structures in association with some excavated burnt mounds (e.g. Liddle (Hedges 1977) and Tougs (Hedges 1986)) and the association between burnt mounds and 'good quality' agricultural land. Dockrill, Bond and O'Connor (1998), in a recent article have noted two flaws with this hypothesis: one is that the domestic furbishments at sites such as Liddle are dominated by a tank, as opposed to the hearth in more regular houses such as Ness of Gruting; secondly the artefact assemblages are usually poor, and may be no more than the result of discard of domestic artefacts in a non-domestic setting. A further difficulty is the association between good land and burnt mounds. This is only true superficially, at a micro level burnt mounds are usually situated on boggy or wet ground adjacent to but not on good agricultural land. Such wet conditions would not be conducive to permanent settlement (Dockrill, Bond, and O' Connor 1998).

Without good artefactual evidence from a series of burnt mounds it appears that their function will remain problematical. Given the number of possible tasks for which shelter and hot water are required it may not be possible or desirable to assign a single function to these monuments. Whether the sites represent settlement as Hedges and Barber believe or whether they are part of a settlement (but without being settlements themselves) network involving houses, field systems and burial monuments as Dockrill proposes is difficult to resolve. Whoever is correct burnt mounds may be considered as direct or proxy evidence of past settlement patterns.

The distribution of burnt mounds differs slightly from that of oval houses, in that oval houses occupy higher, more marginal areas, whereas burnt mounds tend to be situated at lower altitudes in wet areas adjacent to better agricultural land (Canter 1998, Dockrill, Bond, and O' Connor 1998). This spatial difference has been interpreted as representing two separate periods; an earlier period of settlement expansion into marginal areas, and a later period of settlement retraction as a result of worsening climatic conditions during the later Bronze Age (Dockrill, Bond, and O' Connor 1998). There are ,however, several problems with interpreting burnt mounds as a

later settlement pattern.

As noted above, the evidence for worsening climate during the Middle Bronze Age is not clear cut, with climate modelling and some pollen analysts suggesting otherwise (see below). Further, burnt mounds are present in the Shetland landscape from the Late Neolithic onwards e.g. the burnt mound at Tougs which dates from *c.* 2000 BC (Hedges 1986). In any event attempting to use the distribution of burnt mounds as a proxy of middle to late Bronze Age settlement change would be unacceptable without many more dates on this monument class from Shetland.

Some form of settlement contraction is widely believed by archaeologists to have affected the Northern Isles during the later part of the second millennium BC (Turner 1998 (a), Fojut 1993, Ritchie 1995). Explanations of this have tended to emphasize the role of a climatic downturn leading to reduced population and resettlement to more coastal areas. As more research is conducted the nature or even existence of a climatic downturn at this period is being questioned (Bennett *et al.* 1992, Bunting 1994). If the evidence for climatic deterioration is removed archaeologists must therefore reconsider the archaeology of the Middle to Late Bronze Age, either by looking for better climate proxies to demonstrate the climatic downturn, or to consider critically what evidence there is of change in settlement patterns during the Middle to Late Bronze Ages and to seek alternative explanations in the archaeological record.

Subsistence economy

The generally acid soils and the limited nature of the excavated deposits means that there is little direct evidence for the subsistence economy either from preserved seeds or bones. Much economic reconstruction therefore, is dependent upon indirect methods such as artefact collections, field systems and pollen analysis. The in built bias of pollen analysis towards pastoral interpretations has been discussed elsewhere (Edwards 1979 (a)). On Shetland the interpretation of predominately pastoral economies based on the absence of pollen evidence for cereal cultivation needs to be balanced by the evidence of excavation.

In general, the evidence of sites such as Scord of Brouster, South Nesting Hall, Ness of Gruting indicates a mixed economy that included the cultivation of cereals, chiefly barley, through much of the Neolithic and

Bronze Ages (Calder 1955-6, Dockrill, Bond, and O' Connor 1998, Whittle *et al.* 1986). On Shetland the importance of cereals to the subsistence economy is illustrated by the early adoption of soil augmentation by manure, domestic refuse, seaweed, and peat to retain soil fertility. At the South Nesting Hall site this was being practiced from *c.* 3600 uncal. BP (*c.* 2000 cal. BC) (SRR 5255) onwards (Dockrill, Bond, and O' Connor 1998). Similar soil fertilization strategies appear to have been occurring at Tougs and Scord of Brouster on Shetland and at Tofts Ness on Sanday from the late Neolithic onwards (Dockrill and Simpson 1994, Hedges 1986, Whittle *et al.* 1986). The large numbers of bar shares and ard points found on sites from the Northern Isles during the Neolithic and Bronze Age, and the discovery of ard marks at sites such as Kebister are the main artefactual indicators for the tillage of the soil (Clarke 1995 (a), Owen 1998).

The discovery of soil augmentation as part of agricultural practice may indicate the development of an infield/outfield system. Infield/outfield systems have been defined by Welinder (1973) as systems where nutrients are transported from areas away from cultivation (the outfield) either indirectly by animals whose dung is redeposited into the cultivated area, or directly by other means e.g. midden material, seaweed, (scalping where soil or peat is physically moved to cultivated areas), to maintain soil fertility. Such systems can be difficult to identify archaeologically as assessing the contemporaneity of field systems is problematic, and it may not be possible to identify the outfield associated with an ancient infield. One method of identifying an infield is to use soil micromorphology or other physico-chemical techniques to demonstrate the use of manuring to maintain soil fertility (Dockrill and Simpson 1994). The discovery of augmented or plaggen soils at Trowie Loch dating from *c.* 2000 BC suggests that infield/outfield systems have a long history on Shetland.

Animal husbandry was also an important part of the subsistence economy, but the lack of well preserved bone assemblages is a considerable handicap to interpretation. The sites with bone assemblages indicate that the exploitation of sheep, cattle, pig and possibly red deer was occurring from the Neolithic onwards (Calder 1962, Hedges 1986, Noddle 1986). The exploitation of wild resources is poorly understood during the Neolithic and Bronze Ages, but the Iron Age site at Jarlshof has an impressive and diverse species list of both marine and terrestrial mammals, fish and birds, indicat-

ing that during the Iron Age wild resources were used to the full (Platt 1956). Orcadian sites such as Skara Brae and Links of Noltand have also revealed the widespread use of wild resources during the Neolithic (Clarke and Sharples 1985).

The point at which utilization of animal secondary products, such as milk, began is uncertain, not being reflected in either the artefact record or through the analysis of animal bone samples sufficient for such purposes. This would appear to be a priority for further study of the Shetland economy. On Orkney, recent residue analysis of grooved ware pottery has suggested the storage of milk from the Late Neolithic onwards (Jones 1997).

The available evidence suggests that during the Neolithic and Bronze Age a broad based subsistence economy that involved cereal cultivation, and probably the use of marine and avian resources was practiced on Shetland. At some point in the later Neolithic a system of farming involving the growing of cereals on areas of manured plaggen soils began (Dockrill and Simpson 1994, Dockrill, Bond and O'Connor (1998) and Whittle *et al.* (1986)).

Summary

The archaeological evidence suggests that Shetland was first colonized by farming people during the Neolithic in the second half of the fourth millennium BC. This society quickly established a farming economy in many parts of the archipelago based on the cultivation of crops and the keeping of animals. This appears to have been an essentially conservative society and there is little obvious change in the form of houses and the major artefact types over time. During the Later Neolithic and Early Bronze Age a new monument type develops, known as the burnt mound, becoming widespread in the landscape. It appears likely that this monument type had a diverse set of functions that are presently the source of much speculation. Also during the Late Neolithic/ Early Bronze Age soil manuring and improvement led to the development of plaggen or artificial soils in several locations. This development has been described by several authors as a response to soil deterioration (Dockrill and Simpson 1994). An alternative hypothesis for soil manuring would that it was simply a way to increase or maintain yields. At some point variously dated at 1500 BC (Fojut 1994, Turner 1998 (a)) and 1200 BC (Ritchie 1995) this Bronze Age society is

thought to have undergone a recession due to climate change or volcanic eruption (Ritchie 1994) which led to the abandonment of agricultural land. It has been suggested here that the evidence for this climatic deterioration is more complex than previously thought and that many of the archaeological phenomena associated with the Middle to Late Bronze Age such as burnt mounds, date to the early part of the second millennium BC. While some contraction of settlement probably did occur during the later part of the second millennium BC the simplistic environmental determinism favoured by Ritchie (1994), Turner (1998 (a)) and Dockrill, Bond and O'Connor 1998) may be obscuring a more complex interpretation of cultural change.

Vegetation history

The following section will briefly review the vegetation history of Shetland. As this thesis is largely concerned with vegetation change and human impact, this discussion will centre on the development and status of the vegetation at the time of the first postulated human arrivals and any subsequent vegetation changes that have occurred.

Shetland has been the object of palaeobotanical and palynological study since the pioneering work of Lewis in the 1900s and Erdtman in the 1920s (Lewis 1908, 1911, Erdtman 1924). The study of Shetland's vegetation history continued with renewed interest after the publication of Johansen's Holocene diagram in 1975 (Johansen 1975, 1976, 1985). There are now a large number (at least twenty) of published and unpublished pollen studies which describe the vegetation history of Shetland (Birnie *et al.* 1993, Butler 1998). Unfortunately, the bulk of these are not anchored by radiocarbon dates. The absence of radiocarbon dates from most of these pollen diagrams means that it is difficult to correlate the vegetation history from one diagram to another. Consequently, the following discussion will centre on the published, dated diagrams.

Five published radiocarbon dated diagrams are currently available: these are Murraster (mire/lake sediments) (Johansen 1975), Scord of Brouster (mire/lake sediments) (Keith-Lucas 1986), Dallican Water (lake sediments) (Bennett *et al.* 1992), Gunnister Water (lake sediments) (Bennett *et al.* 1993), and Lang Lochs (mire/lake sediments) (Hulme and Shirriffs 1994). In addition mention will also be made of the following three diagrams from Loch of Brunatwatt, Saxa Vord Unst, and Kebister (Edwards and Moss 1993, Whittington and Edwards 1997, Butler 1998).

The key diagrams come from a number of locations in the central and northern areas of the Mainland. The most southerly is that from Lang Lochs from near Lerwick, at 75 m OD, while Loch of Brunatwatt, Scord of Brouster and Murraster are all from the west of Mainland at 25, 30. and 15 m OD respectively. Gunnister is in north Mainland at 75 m a.s.l. and Dallican Water is in the east of Mainland at 55 m OD (see Fig 6.3.). Most of these diagrams are derived from areas away from the better agricultural land and the modern day concentrations of settlement in the south and east and around Weisdale and Tingwall. This somewhat reduces their usefulness for studies of human impact on the Mainland of Shetland as the sectors whose vegetation sequences they contain may always have been marginal to the main centres of settlement.

Whilst the diagrams have some striking similarities, they also display a number of differences as a result of local factors affecting both vegetation development and pollen representation. The diagrams from mires (Murraster, Scord of Brouster and Lang Lochs) tend to be so dominated by locally derived pollen that wider landscape changes are difficult to identify. Below is a summary diagram of the main vegetation changes from Murraster, Lang Lochs, Scord of Brouster, Dallican and Gunnister Water (Fig 6.4).

Open woodland c. 9000-4500 uncal. BP (c. 9000BC-3200 BC)

The status of woodland on Shetland has often been debated, with work by Lewis on plant macrofossils indicating the presence of abundant woodland dominated by birch and hazel (Lewis 1908, 1911). These studies were re-evaluated by Johansen (1975) who undertook pollen analysis at Murraster. Johansen's pollen work indicated a relatively treeless landscape during the early and middle part of the Holocene. Johansen's study and those by Tyldesley on the long distance transmission of pollen to Shetland, (1973a, 1973b, 1973c) suggested that much of the tree pollen observed in Shetland either derived from the Scottish Mainland or Scandinavia, and concluded that woodland was never a significant component of Shetland's vegetation *contra* Lewis.

Research in the 1980's at a number of sites began to overturn the minimalist view of Shetland's woodland (Birnie 1984). In particular Bennett's work at Dallican Water and Gunnister Water suggested that woodland was previous-

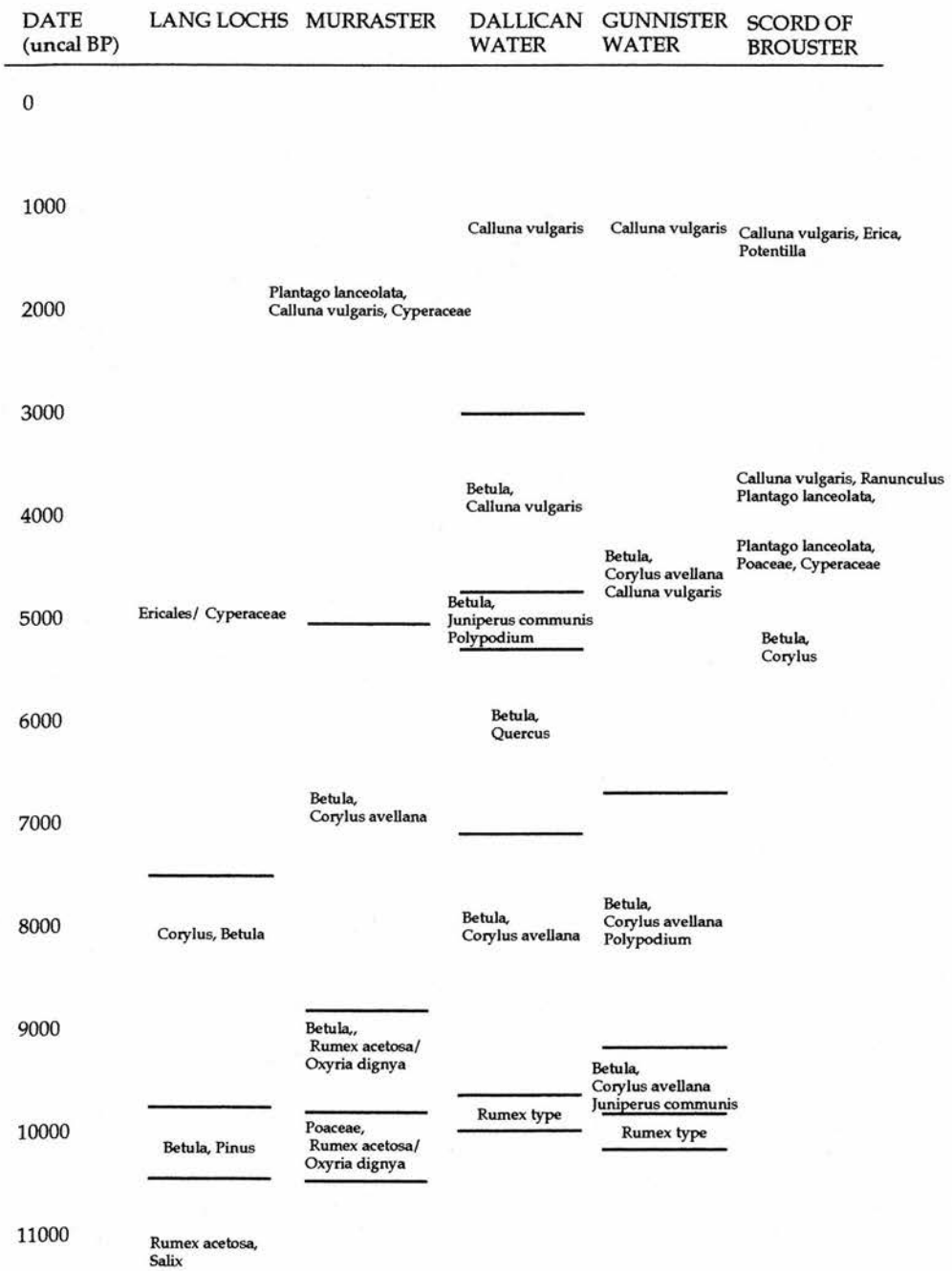


Fig. 6.4 Comparison of main pollen stratigraphic changes from five sites on Shetland (compiled from Bennett& Sharp 1993, Hulme & Shirrifs 1994 & Keith-Lucas 1986)

ly an important component of the native vegetation of Shetland (Bennett *et al.* 1993, Bennett *et al.* 1992). Dallican Water has a wide range of tree pollen types that indicate the local growth of *Quercus* and *Alnus* in addition to *Betula* and *Corylus* during the middle part of the Holocene (Bennett *et al.* 1992). Furthermore the frequency of tree pollen at sites such as Loch of Brunatwatt, 88.5% of TLP, (Edwards 1996) and Scord of Brouster, 80% of TLP (Keith-Lucas 1986) suggest that where suitable shelter existed open woodland developed. The occurrence of macrofossils of *Salix, Alnus, Betula, and Corylus* confirms the pollen evidence of these trees and shrubs (Bennett and Sharp 1993). The lack of macrofossils of *Quercus* does not allow confirmation of the presence of this tree but it is probable that it grew on Shetland during the middle Holocene though it was not a significant member of the woodland community.

The pollen evidence from Scord of Brouster, Dallican Water, Gunnister Water and Loch of Brunatwatt suggests that open *Betula/ Corylus* woodland was present on Shetland from the ninth millennium uncal. BP onwards (Bennett and Sharp 1993). As the upland limit for tree growth is thought to have been 200m during the middle Holocene (Spence 1979), open woodland may have formed the dominant community on the better soils. Fen and bog communities appear to have been forming on the less well drained, poorer lowland soils (Butler 1998) during the middle Holocene.

The ground flora of the open woodland included ferns and tall herbs including Poaceae, Apiaceae, *Filipendula* and *Urtica.* It seems possible that in some areas this tall herb community may have been the dominant community (Whittle *et al.* 1986). There is pollen evidence from Murraster, Lang Lochs and Dallican Water to suggest that areas of *Calluna* dominated heath began to develop from *c.* 7500 uncal. BP on poor waterlogged soils.

Mesolithic

The recognition that human activity during the Mesolithic may have altered vegetation is based partly on ethnographic analogy with indigenous societies (Mellars 1976) and partly on practical and theoretical studies in the North Yorkshire Moors (Simmons 1975). From these early studies an extensive literature has developed which discusses the main palynological indicators of human activity in the Mesolithic. Chief among these is the microcharcoal record; other more contentious indicators are increases in

Corylus, Alnus and non arboreal taxa such as Poaceae (Edwards and Ralston 1984, Edwards 1990).

In the Northern Isles the recognition of a possible Mesolithic presence based on palynological studies is a relatively recent development (Bennett 1992, Bunting 1994, Edwards 1996). The main evidence for Mesolithic interference with vegetation on Shetland is defined by rises in microcharcoal frequency. Which are associated with decreases in ferns and arboreal pollen taxa and increases in non-arboreal taxa in particular Poaceae and *Calluna* (Edwards 1996, Bennett *et al.* 1992, and Bunting 1994).

Despite the large number of pollen diagrams from Shetland only three contain fine resolution analyses of microcharcoal and pollen that allow interpretation of the Mesolithic record (Tipping 1996, Edwards 1996). These are Loch of Brunatwatt (Edwards and Moss 1993), Dallican Water (Bennett *et al.* 1992) and Gunnister Water (Bennett *et al.* 1993). No increases in charcoal or changes in vegetation associated with Mesolithic activity are present at Gunnister Water. At Dallican Water there are rises in microcharcoal, Poaceae, *Pteridium aquilinum* and reductions in ferns and *Polypodium* spores between *c.* 7400 and 5400 uncal. BP (interpolated dates), but curiously tree pollen values are not affected. At Loch of Brunatwatt a shorter undated episode described by Edwards as "temporary" also sees increases in microcharcoal, Poaceae and *Calluna* together with declines in birch, and *Pteridium aquilinum*.

At Dallican Water Bennett (*et al.* 1992) argue that Mesolithic hunter gatherers together with an imported red deer population first arrived on the Island at *c.* 7400 uncal. BP. It was this population that affected the vegetation and caused the increase in microcharcoal frequencies. Further they assume that both the human and deer population later became extinct at *c.* 5400 uncal BP and that the forest then regenerated prior to the first Neolithic colonization at *c.* 4000 uncal BP. It should also be noted that except at Loch Brunatwatt, where a short microcharcoal increase is observed no other pollen sites on Shetland have produced any evidence for Mesolithic activity.

A causative role for climatic effects or autogenic vegetation changes as suggested by Tipping (1996) has not been considered by the authors of the Dallican Water and Loch of Brunatwatt studies. However, the possibility that the fluctuations in the microcharcoal records may have a cause other than human activity should be considered. The lack of archaeological evidence for a Mesolithic presence on Shetland, and uncertainties as

to the causation of the microcharcoal record at both Loch of Brunatwatt and Dallican Water, suggest that there may have been no significant Mesolithic presence on Shetland, and that prior to the arrival of the first farmers the vegetation of Shetland had yet to be affected by human or herbivore activity.

Human activity in the landscape

The role of human interference in the overall development of the current Shetland landscape is thought to have been considerable. Spence (1979) considered human associated activities, in particular grazing animals, as major vectors in the shaping of the modern Shetland landscape. This may not in fact be the case. Certainly, in lower, less exposed, areas there may formerly have been more trees and shrubs, but the available evidence from both the Faroes and Shetland (Bennett *et al.* 1992, Johansen 1985) suggests that heath and blanket bog may have come to dominate the landscape with or without human interference, and indeed that these vegetation communities were established and expanding prior to human arrival.

Neolithic

The isotopic dates from pollen diagrams for human impact on vegetation as a result of farming activity fall into two groups (Table 6.1). The available dates suggest that the onset of farming activity across Mainland was not synchronous; rather, a set of fourth millennium BC dates can be dis-

Site	Date BP (cal BC)
Dallican Water	c. 4000 BP (c. 3400 BC)
Gunnister Water	2920 BP (990-790 BC)
Scord of Brouster	4680 BP (3540-3350 BC)
Murraster	4650 BP (3700-3100 BC)
Lang Lochs	4500/ 3000 BP (c.3000/ 1000 BC)
Kebister	4540 BP (c. 3150 BC)
Shurton Hill	4750 BP (3650-3370 BC)

Table 6.1 Dates for the initial human farming impact from a number of pollen diagrams from Shetland. (compiled from Bennett& Sharp 1993, Hulme & Shirrifs 1994, Keith-Lucas 1986, Whittington 1980, Butler 1998)

tinguished from a series of second millennium BC dates.

The open woodland and tall herb vegetation of the middle Holocene declines after human impact to be replaced by open grassy conditions and heathland at most sites. The diagrams from Scord of Brouster and Dallican Water however show some recovery of tree pollen values after the initial clearance. The initial clearance episodes lasted approximately 400 years at Dallican Water and 500 years at Scord of Brouster. At Dallican Water the regeneration of woodland was of approximately 400-500 years duration, whilst at Scord of Brouster this was considerably shorter *c.* 200-300 years (Bennett *et al.* 1992, Keith-Lucas 1986). The local extinction of woodland at Dallican Water, Gunnister Water and Scord of Brouster occurs at 3350 uncal. BP (*c.*1600 BC), 2920 (1000 BC) and *c.* 3450 uncal. BP (1800 BC) respectively.

Blanket bog, climatic deterioration, human impact or autogenic change?

After the destruction of woodland associated with human activity the next major change in vegetation is the marked expansion of heathland and blanket bog over much of Mainland (Bennett *et al.* 1992, Bennett and Sharp 1993, Spence 1979). The role of climate, volcanic eruption, human impact and autogenic change have all been put forward as causative factors for the this significant change on Shetland and elsewhere (Lamb 1977, Spence 1979, Harding 1982, Keith-Lucas 1986, Bennett *et al.* 1992, Blackford 1993).

Site	Date BP (cal BC)
Lang Lochs	c.5000 BP (c. 3785 BC)
Shurton Hill	4750 BP (3650-3370 BC)
Saxavord, Unst	c. 3760 BP(c.2000 BC)
Scord of Brouster	c. 3450 BP (c. 1750 BC)
Dallican Water	c. 3200 BP (c.1550 BC)
Gunnister Water	2920 BP (990-790 BC)

Table 6.2 expansion of *Calluna vulgaris* in Shetland pollen diagrams with interpolated and calibrated chronologies (compiled from Bennett& Sharp 1993, Hulme & Shirrifs 1994, Keith-Lucas 1986, Whittington 1980, Whittington & Edwards 1997)

The widespread development of heathland and blanket bog on Shetland has been thought to be the result of climatic deterioration during

the sub Boreal in the middle of the second millennium BC (Keith-Lucas 1986, Butler 1998). Recent climatic modelling (Kutzbach and Guetter 1986) and an appreciation of the interpretative difficulties of pollen data in demonstrating clear climate signals (Whittington and Edwards 1997), has however, led to a reassessment of later Holocene climate change as it affects the Northern Isles (Bennett *et al.* 1992, Bunting 1996). The current approach, based on atmospheric modelling predicts a stable climate for much of the later Holocene of Shetland with temperatures 1 °C lower than at 9000 uncal. BP (Kutzbach and Guetter 1986). This new climatic model has led to a hypothesis for blanket bog and heathland development based on the interaction of a generally wet climate with human activity occurring alongside autogenic changes to soils and vegetation (Bennett *et al.* 1992). Supporting evidence for this model is found in studies of vegetation history from the Faroes and Orkney (Bunting 1996, Johansen 1975, Johansen 1985).

The following table (Table 6.2) provides a chronology for the development of *Calluna vulgaris* dominated heathland and bog. The development of blanket peat is here taken as the increase in *Calluna* to percentage values in excess of 50% of TLP. In most cases this is given as an interpolated date marked by *c.* in Table 6.2 or as a 2 σ radiocarbon date. The Table demonstrates the lack of synchroneity of this change in the vegetation of Shetland. The spread of dates is further supporting evidence for the origin of blanket bog as a local response to the interaction of bedrock, aspect and exposure with vegetation and human interference. However, as noted above, the possibility of a climatic role in the onset of blanket bog cannot be discounted and this possibility will be reexamined in the light of the results from Trowie Loch below.

The Holocene record from c. 3500 uncal. BP (c. 1800 BC) onwards

The later Holocene pollen stratigraphic record is largely a monotonous picture dominated by local Cyperaceae pollen and *Calluna vulgaris* in the mire sequences (Scord of Brouster, Murraster, Lang Lochs), whilst in the lake diagrams the pollen component is dominated by *Calluna vulgaris* reflecting the prevalence of moorland and heathland communities in their vicinities. The increases in pollen of *Plantago lanceolata* at Lang Lochs, and the dramatic reduction of tree pollen at Dallican Water and Gunnister Water between *c.* 2000 BC and 1200 BC led Bennett to consider that "the main peri-

od of landscape change associated with permanent occupation took place at *c.* 3000 uncal. BP"(*c.* 1260 BC) (Bennett *et al.* 1993 p.98). The dating of permanent landscape change by Bennett to *c.* 1200 BC is interesting as it is a time when many archaeologists (Turner 1998 (a), Dockrill, Bond and O' Connor 1998, Ritchie 1995, *cf.* Burgess 1985, 1989) would consider that settlement on Shetland was undergoing a prolonged period of stress as a result of a climatic downturn

The increasing amounts of heathland and blanket bog in the second millennium BC has been correlated with a largely hypothetical settlement hiatus during this period (Turner 1998 (a), Dockrill, Bond and O' Connor 1998, Ritchie 1993). The increases in blanket bog and poorer heath vegetation has often been equated with a retreat of settlement to more fertile coastal areas (Fojut 1994, Dockrill, Bond and O'Connor 1998). Whether there really was a mid second millennium BC downturn in settlement on Shetland requires more work and dating of sites to demonstrate. Presently, new pollen evidence suggests that an expansion of settlement (possibly temporary) was occurring during the second millennium BC.

Summary

The history of vegetation as recovered through pollen analysis on Shetland is one in which local factors of aspect, soil type and bedrock, coupled with a wet climate, interacted with migrating plant species to produce a diverse landscape prior to the onset of human activity in the Neolithic. Open woodland of mainly birch and hazel with an understorey of tall herbs, including ferns and umbellifers, appears to have dominated the better soils during the early and middle Holocene. Elsewhere, on higher, more exposed locations, heathland was present from early in the Holocene e.g. Murraster (Johansen 1975) and Lang Lochs (Hulme and Shirriffs 1994). Exposed coastal locations probably consisted of grassy swards (Spence 1979).

The possible Mesolithic intervention noted by Edwards and Moss (1993) and Bennett (*et al.* 1992) is not considered by either of these authors to have significantly altered the vegetation of Mainland, as both authors envisage a period of abandonment and recovery of vegetation to its earlier condition after the first hypothetical human interference. It must be stressed, however, that there is to date no archaeological evidence for a Mesolithic of Shetland and that the palynological evidence for Mesolithic occupation has

been questioned (Tipping 1996). It may be prudent to await further research on this issue and to consider that the evidence for a Mesolithic of Shetland is presently far from conclusive.

Human impact on vegetation associated with the arrival of farming people is dated from the middle of the fourth millennium cal BC in several pollen diagrams (e.g. Scord of Brouster, Shurton Hill, Murraster (Keith Lucas 1986, Whittington 1980, Johansen 1978). Woodland vegetation underwent a series of reductions after the initial impact of farming and appears to have become virtually extinct on the Shetland Islands by around the end of the second millennium BC (Bennett *et al.* 1993).

The vegetation history of much of the Shetland landscape thereafter is one in which pasture, heath and blanket bog dominate (e.g. Dallican Water, Scord of Brouster etc.). In such circumstances investigating later changes in human activity by their vegetational impacts may be beyond the resolution of pollen analyses from mires and lakes (Bennett *et al.* 1992). Instead, more site based methods involving archaeobotany and related disciplines may prove to be more informative of human relationships with the surrounding landscape.

Background to the South Nesting Palaeolandscape Survey

The palynofacies analysis reported here formed part of a multidisciplinary study of the palaeolandscape of South Nesting, Shetland (Fig. 6.1). The aim of this study was to investigate burnt mounds in their contemporary landscape (Dockrill, Bond, and O'Connor 1998). The palaeolandscape study of South Nesting incorporated archaeological survey, palaeoenvironmental studies (of which this is one), and the partial excavation of a number of sites.

The South Nesting peninsula was chosen as it has a known concentration of burnt mounds, and is an area with limestone bedrock, which it was thought would aid preservation of bone and other environmental information. A number of archaeological sites were selected for excavation: these included two burnt mounds, in the Vadill of Garth, and a prehistoric oval house with its associated field system, buried soil and a burial cairn at South Nesting Hall (Fig 6.1).

Aims and objectives of the palynofacies studies at Trowie Loch, South Nesting, Shetland

The aim of this study was to provide environmental data relating to the periods prior to and contemporary with the archaeological site near South Nesting Hall. As Shetland is a remote archipelago grazing herbivore populations were absent until their introduction by humans in prehistory. A major objective was to test the hypothesis that changes in the palynofacies assemblage in the sediments would occur as the result of the introduction of grazing herbivores. A secondary objective was to examine the palynological evidence for vegetation changes in relation to the evidence for intensive farming activity at the South Nesting Hall site after *c.* 2000 BC.

Results

Introduction

This section commences with a description of the sediments in the Trowie Loch basin and a discussion of the sampling points. This is followed by a description of the sediment stratigraphy and the results of the radiocarbon dating. The results of the pollen and palynofacies analyses are presented in a short discussion and series of diagrams. The results of the analysis are then discussed in relation to other pollen analyses on Shetland and Orkney and the recent archaeological survey and excavation of South Nesting.

The Trowie Loch Basin

Trowie Loch is located in a small partially infilled basin. It is fed by a small stream from the Loch of Benston to the West and drains through a narrow rock cut outfall into the Vadill of Garth to the East. The Vadill of Garth is a tidal inlet at the present day. The presence of two eroding burnt mounds on the bank of the Vadill of Garth (Dockrill, Bond and O'Connor 1998) suggests that there has been a relative rise in sea level since the Bronze Age. Trowie Loch is marked as being above Mean High Water Springs on the 1971 OS 1:1250 map but at the time of sampling (June 1995) Mean High Water Springs appeared to be as far up the basin as the SW arm of the Loch. How recently Trowie Loch has been affected by tidal action is not currently known but a comparison of the 1880 (Six Inch) and 1971 (1:1250) editions of the OS maps indicate that the Loch has been enlarged, possibly as a result of tidal action or peat cutting or a combination of the two (see Fig 6.5).

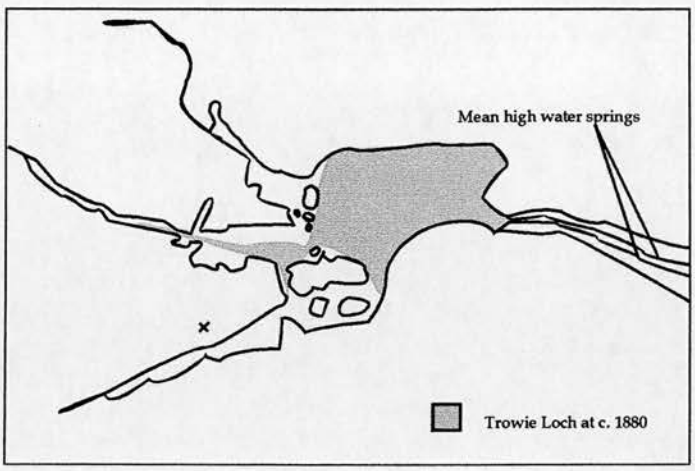


Fig 6. 5 Changes in the extent of Trowie Loch between 1880 and 1971 (Based on the O.S. six inch (1880) and 1:1250(1971) editions.)

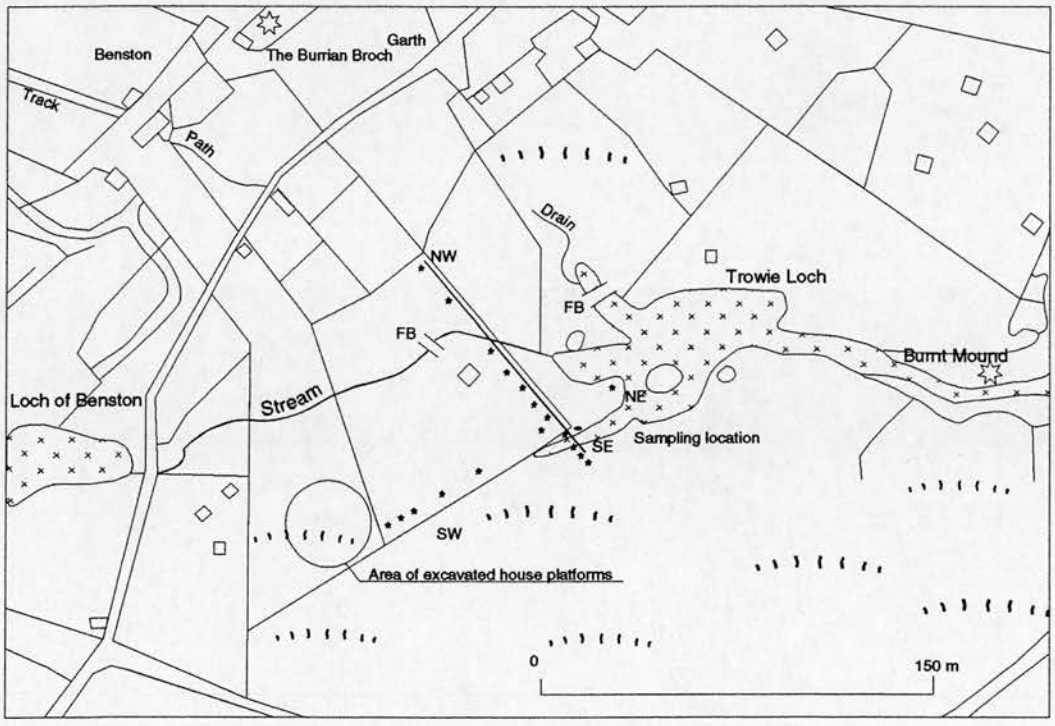


Fig. 6.6. Location of trial coring transects at Trowie Loch.

Reconnaissance of the basin deposits was made by two perpendicular traverses with a dutch corer (Fig. 6.6, 6.7). The stratigraphy of the deposits along the SW-NE traverse is straightforward, with basal blue gray clays, overlain by lake gyttjas which in turn are overlain by peats. The sequence deepens to the edge of the of the present day lake. The SE-NW tra-

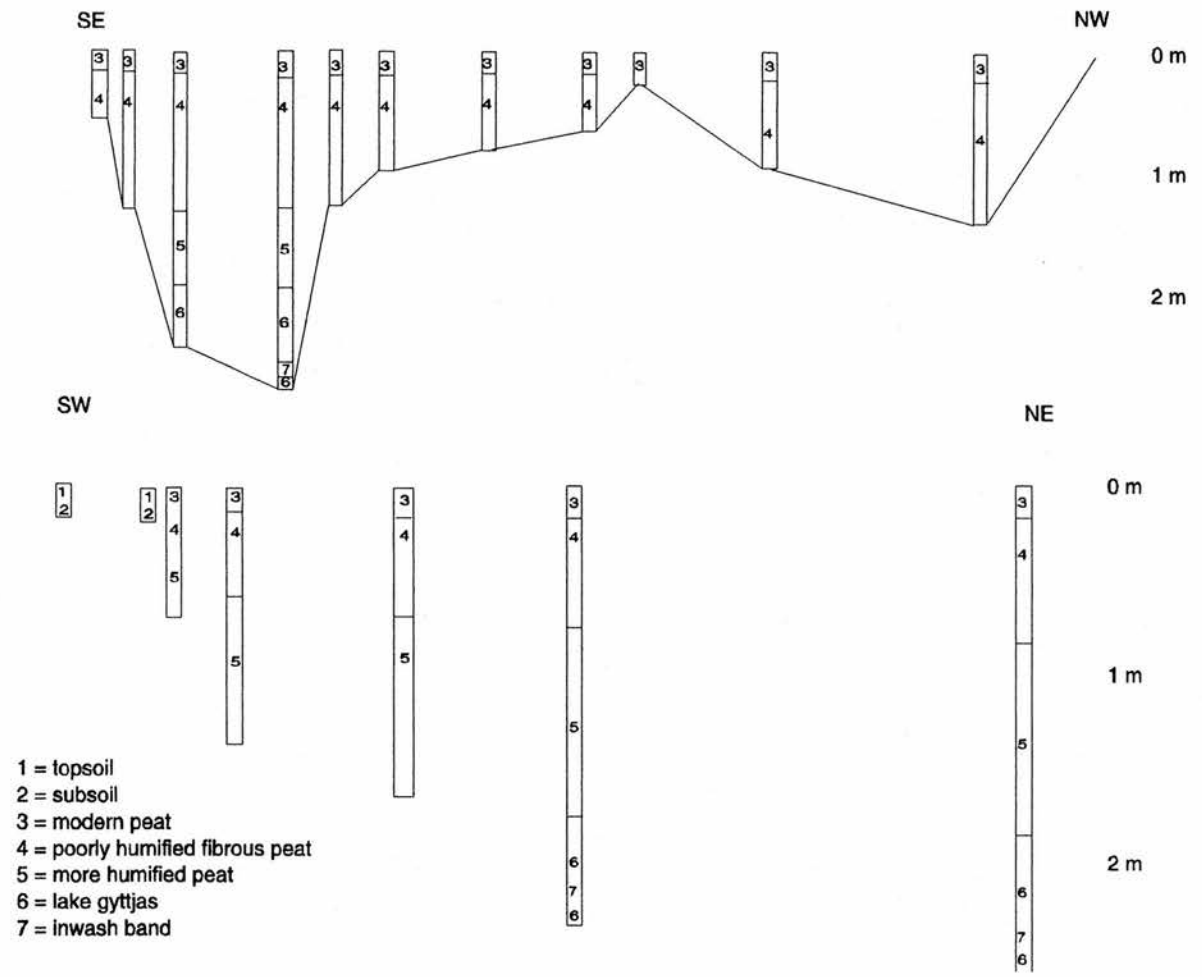


Fig. 6.7 basin sediments and cross sections from trial corings at Trowie Loch.

verse is more complex as the basin is bifurcated, with an incised, probably Late Pleistocene, palaeochannel where the sampling site lies. The channel infill is the same as that of the lake, suggesting that for part of the post glacial it formed an arm of the loch. NW of this palaeochannel the deposits are shallower, and comprise peats overlying clays. The modern drainage channel of the Loch of Benston flows through on the Northern margin of the basin, away from the palaeochannel.

Within the lake sediments of the SW -NE transect a layer of coarse sand and gravel was located. This thinned gradually from *c.* 8cm thick to 4 cm inland, and will be discussed in greater detail below.

Sampling location and sediment stratigraphy

Details of sampling methodology and sample collection were described in Chapter 3. The sampling site chosen is on the edge of the modern day enclosed land. The vegetation consisted of a grazed community typical of poor pasture. The sampling area chosen was as close as possible to the excavated house sites whilst retaining a depth of deposits likely to provide a

Depth	Description
0-12 cm	modern peat sharp transition to
12-54 cm	strongly humified dark brown peat with occasional flecks of quartz gradual transition to
54-120 cm	orange brown sedge peat with frequent macrofossils gradual transition to
120-180 cm	dark orange brown peat with occasional woody macrofossils sharp transition to
180-240 cm	grey green gyttja with occasional flecks of silt and sand sharp transition to
240-244 cm	inwash band of blue grey coarse sand sharp transition to
244-250 cm	grey green gyttja with occasional flecks of silt and sand sharp transition to
250 cm	pale blue clay

Table 6.3 Sediment stratigraphy at Trowie Loch

record of vegetation change for the period under investigation.

The stratigraphy at Trowie Loch is recorded in Table 6.3. The sequence demonstrates a switch in sedimentation from lake sediments to a basin mire at 180 cm. The lake sediments include a 4 cm thick layer of coarse sand and gravel at 240 cm. The top 12 cm represented modern peat and this deposit was not analysed.

Radiocarbon dating

As discussed in Chapter 3 radiocarbon dates were only sought from the mire sediments, as the lake gyttjas may have been affected by the hard water effect (Aitken 1990, Housley and Harkness pers. comm.). Funds, generously provided by the Shetland Amenity Trust, were available for three radiocarbon dates. Given the funding constraints, and the overall aim of the study, samples were selected from contexts which were estimated to be most informative about periods of human activity. The lowest sample in the sequence was for the horizon between LPAZ TL2 and LPAZ TL3a where an increase in the amount of microcharcoal particles and an abrupt decline in the frequency of tree pollen is associated with agricultural clearance (*cf.* Whittle *et al.* 1986, Bennett *et al.* 1992). The next boundary to be dated was between LPfAZ TL3 and LPfAZ TL4 which marks the end of a zone of increased charcoal and type ASM029 (*Sporomiella* type) frequencies. The final sample came from the boundary between LPAZ subzones TL3b and TL3c where a large increase in the frequency of *Calluna vulgaris* pollen occurs.

A time depth curve for the mire sediments at Trowie Loch has been constructed (Fig. 6.8) which shows a decrease in sedimentation rate

Laboratory number	Mean depth (cm)	Sediment thickness (cm)	Fraction	14C age BP	1 σ	δ13C%	cal. BC
Beta-116595	150	4	humin/humic	4830	60	-25	3721-3502
Beta -116597	96	6	humin/humic	4460	50	-25	3145-3019
Beta-116596	35	6	humin/humic	3550	50	-25	1981-1742

Table 6.4 Radiocarbon dates from Trowie Loch

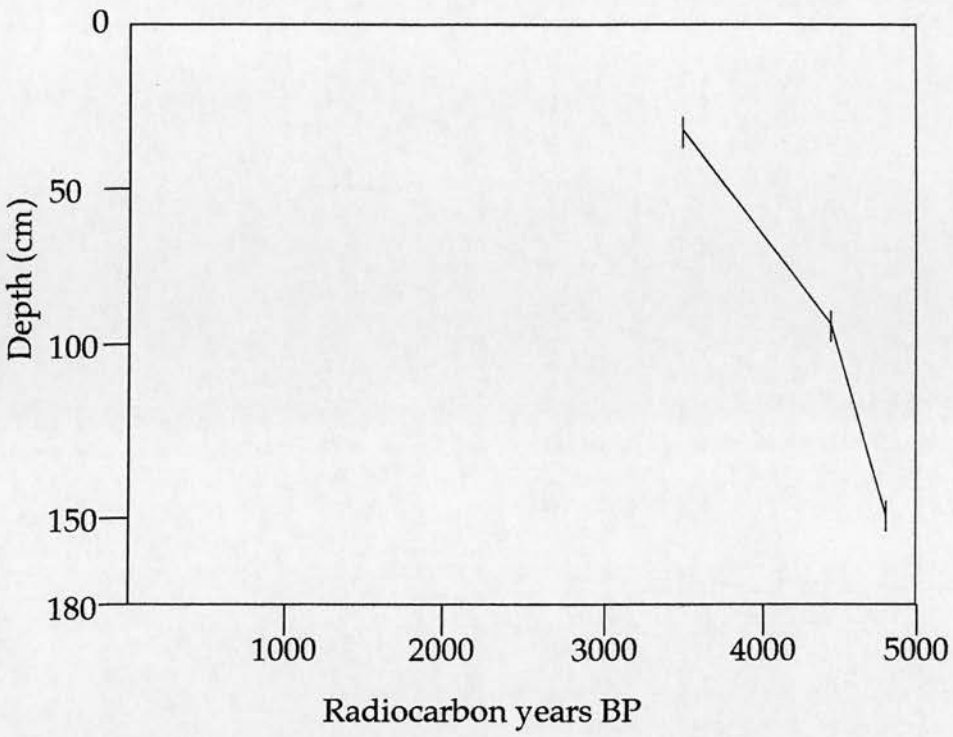


Fig 6.8 Time depth curve for sediments from Trowie Loch.

after 96 cm. The time depth curve is undoubtedly an oversimplification of the sedimentation rate over the span of the core, as only three radiocarbon dates were obtained.

Tephrachronology

No concentrations of tephra were located during the analysis of all the sediments, despite prolonged examination of the slides by the author and D. A. Dugmore (Dept. of Geography, University of Edinburgh). The study of tephra in sediments from the Northern Isles is a comparatively recent development (Dugmore, A.J. 1989, Bennett *et al* . 1992). Consequently the distributions and locations of tephra layers in the British Isles are poorly understood (Bennett 1994).

Several attempts at locating tephra layers in sediments from the Northern Isles are known to the author (Bennett *et al.* 1992, Bennett *et al.* 1993, Bunting 1994, Bunting 1996). However, these studies suggest that there is some variation in the deposition of tephra layers from site to site. For example, Crudale Moss and Quoyloo meadow on the West Mainland of

Orkney contain tephras thought to be related to the Saksunarvatun eruption in *c.* 9210 uncal. BP (Bunting 1994). However, no other tephra layers were located at these sites. In Shetland a tephra layer dating to *c.* 9210 uncal. BP is known from Dallican Water and Gunnister Water (Bennett *et al.* 1992, 1993). Later tephra falls have proved harder to identify with a possible tephra layer relating to Hekla 3 or 4 at Dallican Water (Bennett *et al.* 1992) but no similar layer at Gunnister Water (Bennett *et al.* 1993). Their absence at Trowie Loch suggests that tephra layers are not consistently present in the sediments of the Northern Isles. Unless tephra layers can be located reliably in sediments its use as a widely applicable dating method is likely to be circumscribed.

Dating of the lake sediments

No absolute dates are available for the lake sediments. However, the interface between the mire and lake sediments may be estimated by back projection of the time depth curve, which gives a date of approximately 5000 uncal. BP at 180 cm. The basal sample of the core (250 cm) indicates that sediment build up began after the arrival of *Corylus*, but prior to the immigration of *Alnus* into Mainland. *Corylus* was present in north east Mainland at Gunnister Water from *c.* 9350 uncal. BP (Bennett *et al.* 1992) whilst *Alnus* pollen is consistently represented in Shetland pollen diagrams from as early as 8400 uncal. BP (Bennett and Sharp 1993). Their respective presence and absence suggests sedimentation began in the basin at *c.* 9000 uncal. BP.

Local pollen assemblage zones (LPAZ)

The percentage pollen diagram (Fig. 6.9) from Trowie Loch is divided into three local pollen assemblage zones (Table 6.5). Pollen concentration and pollen influx data are presented in Fig. 6.10. As discussed in Chapter 3, minor pollen taxa are presented in tabular form (Table 6.6). Loss on ignition data is presented in Fig. 6.11. Pollen preservation was excellent .

LPAZ	Depth range (cm)	Date range uncal BP
LPAZ TL3c	30-12	3550-3000
LPAZ TL3b	112-30	4500-3550
LPAZ TL3a	154-112	4830-4500
LPAZ TL2	180-154	5000-4830
LPAZ TL1	250-180	9000-5000

Table 6.5 local pollen assemblage zones at Trowie Loch

LPAZ TL1 (250-180 cm, c.9000 - 5000 uncal. BP) *Betula- Corylus*-Filicales

The basal sample is dominated by *Betula* and *Corylus.* Above this sample at 244 cm a 4 cm thick sand layer was deposited, which represents a hiatus in lake gyttja sedimentation. After 248 cm *Betula, Corylus* and Pteropsida continue to dominate and *Alnus* is a consistent component of the pollen spectra at low levels (<3 % of TLP). A heathland component is indicated by constant *Calluna vulgaris* values at *c.* 5% of TLP and occasional *Empetrum* and *Juniperus* pollen. A sharp peak in *Corylus* pollen occurs in the sample at 184 cm where values rise to nearly 30% of TLP. The zone ends abruptly with a change in lithology from lake gyttjas to basin peats.

LPAZ TL2 (180-150 cm, 5000-4830 uncal. BP) Cyperaceae-*Betula-Corylus*

The principal pollen change in this zone is the result of a hydrological change within the arm of Trowie Loch from lake sediments to basin peats. Local pollen input from Cyperaceae increases rapidly throughout the zone, suppressing values of non-mire taxa principally *Betula, Corylus* and *Calluna vulgaris.* Concentration values of *Betula, Corylus,* and *Calluna vulgaris* show some reduction with the change to basin peats (Fig. 6.11). Charcoal values remain low throughout the zone.

LPAZ TL3 (154-12 cm, 4830- 3000 uncal. BP) Cyperaceae-Poaceae-*Plantago lanceolata*

This zone is marked by a slight increase in charcoal, the beginning of a continuous curve of *Plantago lanceolata* and a marked decline in tree and shrub pollen from 152 cm. This zone is divided into three subzones.

LPAZ TL3a (154-116 cm, 4830-4500 uncal. BP) Cyperaceae-*Betula*--Poaceae

An initial phase of woodland clearance occurs between samples 152-148 cm which is followed by a recovery of woodland taxa at much reduced levels to 116 cm. During this phase of woodland recovery the trend of the charcoal curve is one of continuous increase to the end of the zone. Single cereal grains of *Hordeum* type pollen were identified in samples at 144 and 128 cm. During this zone declines in the frequency of *Filipendula,* Pteropsida, and *Polypodium vulgare* pollen also occur. The end of the zone is

marked by a decline in tree pollen frequency, a slight recovery in the values of *Filipendula* and a gradual increase in heathland taxa.

LPAZ TL3b (116-32 cm, 4500-3550 uncal. BP) Cyperaceae-Poaceae -*Plantago lanceolata*

This subzone is completely dominated by local Cyperaceae pollen. This has resulted in the suppression of frequencies of pollen taxa not derived from the mire surface. Two periods of grassland expansion are indicated the first between samples 96-88 cm and the second at 64 cm. After 96 cm there is a decline in *Filipendula* and Pteropsida. Two increases in the charcoal curve occur at 96 cm and 48 cm.

LPAZ TL3c (24-12 cm, 3550-3000 uncal. BP) Cyperaceae-*Poaceae- Calluna vulgaris*

This subzone is distinguished by a large rise in *Calluna vulgaris* frequencies. Up to this point *Calluna vulgaris* had been a minor component of the vegetation within the basin.

Palynofacies assemblage zones (LPfAZ)

Four main LPfAZ and a number of subzones were recognized in the sequence from Trowie Loch (Table 6.6). Approximations of the duration of the subzones based on the time depth curve are also given in Table 6.6. Percentage data relating to fungal, algal, incertae cedis fossils and area data of palynodebris is presented in Fig. 6.12, rare fungal and other non-pollen taxa are tabulated in Table 6.8. Together with the pollen data the palynofacies evidence suggests a sequence of wet and dry phases on the mire.

LPfAZ	Depth range (cm)	Estimated start date of zone uncal BP
LPfAZ TL4b	46-12 cm	3150 BP
LPfAZ TL4a	92-46 cm	4460 BP
LPfAZ TL3	134-92 cm	4780 BP
LPfAZ TL2c	146-134 cm	4780 BP
LPfAZ TL2b	164-146 cm	
LPfAZ TL2a	178-164 cm	4995 BP
LPfAZ TL1	250-178 cm	9000 BP

Table 6.6 Local palynofacies assemblage zone at Trowie Loch

Comparitive fungal spore types from the studies of van Geel and Clarke to those identified at Trowie Loch are presented in Table 6.9.

LPfAZ TL1 (250-178 cm, 9000-4995 uncal. BP)

The lake sediments are dominated by microfossils of pollen and algae, as the cumulative diagram in Fig 6.9 demonstrates. The algal sequence at the base is dominated by *Tetrahedron minimum* and *Botryococcus* (Figs. A5 9.2, 8.9). There are increases in values of both *Pediastrum* , (Fig. A5 8.7) and *Botryococcus* after 224 cm. Fungal remains are few throughout the sequence, suggesting little input of fungal spores or hyphae from terrestrial sources or via air transport. Levels of invertebrate remains, amorphous organic material and plant cells are above 50 mm^2 cm^3 throughout this zone The top of the zone is marked by increases in *Gleotrichia* type, (Fig. A5 8.8), hyphal values, well preserved plant cells, amorphous organic material and decreases in *Pediastrum, Botryococcus* and invertebrate fragments.

LPfAZ TL2 (178-134 cm, 4995-4780 uncal. BP)

This zone is sub divided into three subzones. The change to a mire sedimentary regime is particularly marked by the rise in fungal spores types ASM014 (*Gaeumannomyces* type), ASM043 (*Anthostomella fuegiana* type) and agglomerate, phomoid and toruloid fragments (Figs. A5. 3.9, 5.4, 8.5, 8.6). There is a decline in invertebrate fragments and plant cells, but gradual increases in amorphous organic materials, gels, hyphae and charcoal.

Subzone LPfAZ TL2a (178-164 cm)

This subzone is marked by peaks in possible algal types ASI021, ASI035 (Figs. A5 1.5, 1.10), and fungal spore type ASM043 (*Anthostomella fuegiana* type). During this subzone *Pediastrum* and *Tetrahedron minimum* are absent and values of *Botryococcus* decline markedly. Hyphal values increase within the subzone.

Subzone LPfAZ TL2b (164-146 cm)

This subzone is defined by steep increases in, and maxima of, fungal spore type ASM014 (*Gaeumannomyces* type) at 20% and toruloid fragments at 25%. This subzone also sees the appearance of fungal spore type ASM029 (*Sporomiella* type). Levels of invertebrate fragments and well preserved plant cells remain low but there is a gradual increase in amorphous

organic material, and hyphal frequencies.

Subzone LPfAZ TL2c (146-134 cm)

This subzone has a decline in fungal spore types ASM014 (*Gaeumannomyces* type), ASM043 (*Anthostomella fuegiana* type), and in toruloid fragments. Overall, the frequency of fungal spores is lower than the high levels of the previous subzone. Correspondingly, there is an increase in the amount of algal microfossils, particularly species of Zygnemataceae and *Spirogyra*, (Fig. A5 9.4, 9.1) which is accompanied by increases in amorphous organic material, gels and hyphae.

LPfAZ TL3 (134-92 cm, 4780-4460 uncal. BP)

This zone is dominated by high levels of all types of palynodebris, low frequencies of algal microfossils (between 0-5%), and high levels of fungal microfossils, reaching 90% of all remains located. The fungal spore assemblage is dominated by two types: ASM043 (*Anthostomella fuegiana* type) and DII002, (Fig. A5 6.5). During this phase the frequency of fungal spore type ASM029 (*Sporomiella* type, (Fig. A5 4.1)) increases to a maximum of 21% whilst also at 96 cm are increases in fungal spore types ASM004 (*Chaetomium/Lophitrica* type, (Fig. A5 3.3)) and ASM010 (*Podospora* type, (Fig. A5 3.7)).

LPfAZ TL4 (92-12 cm, 4460-3150 uncal. BP)

This zone has been subdivided into two subzones. It is distinctive in having a steep decline of all types of palynodebris and an increase in the frequency of fungal spore type ASM014 *(Gaeumannomyces* type).

LPfAZ TL4a (92-48 cm)

This zone is marked by a increase in algal microfossils, especially *Pediastrum, Botryococcus* and ASI021. Values of fungal spore type ASM014 (*Gaeumannomyces* type) increase to 20%, and number of miscellaneous fungal spore types such as toruloid, phomoid, agglomeration and MUI012 (Fig. A5 7.5) increase in number and frequency of occurrence throughout this zone.

LPfAZ TL4b (48- 12 cm)

This zone has a continuous presence of fungal spore types ASM014, ASM029, and MUI012 but shows an abrupt decline in all types of palynodebris and an increase in hyphae. At 16 cm there is an almost complete absence of most microfossil types except pollen, which rises to nearly 90 % of the recovered microfossils.

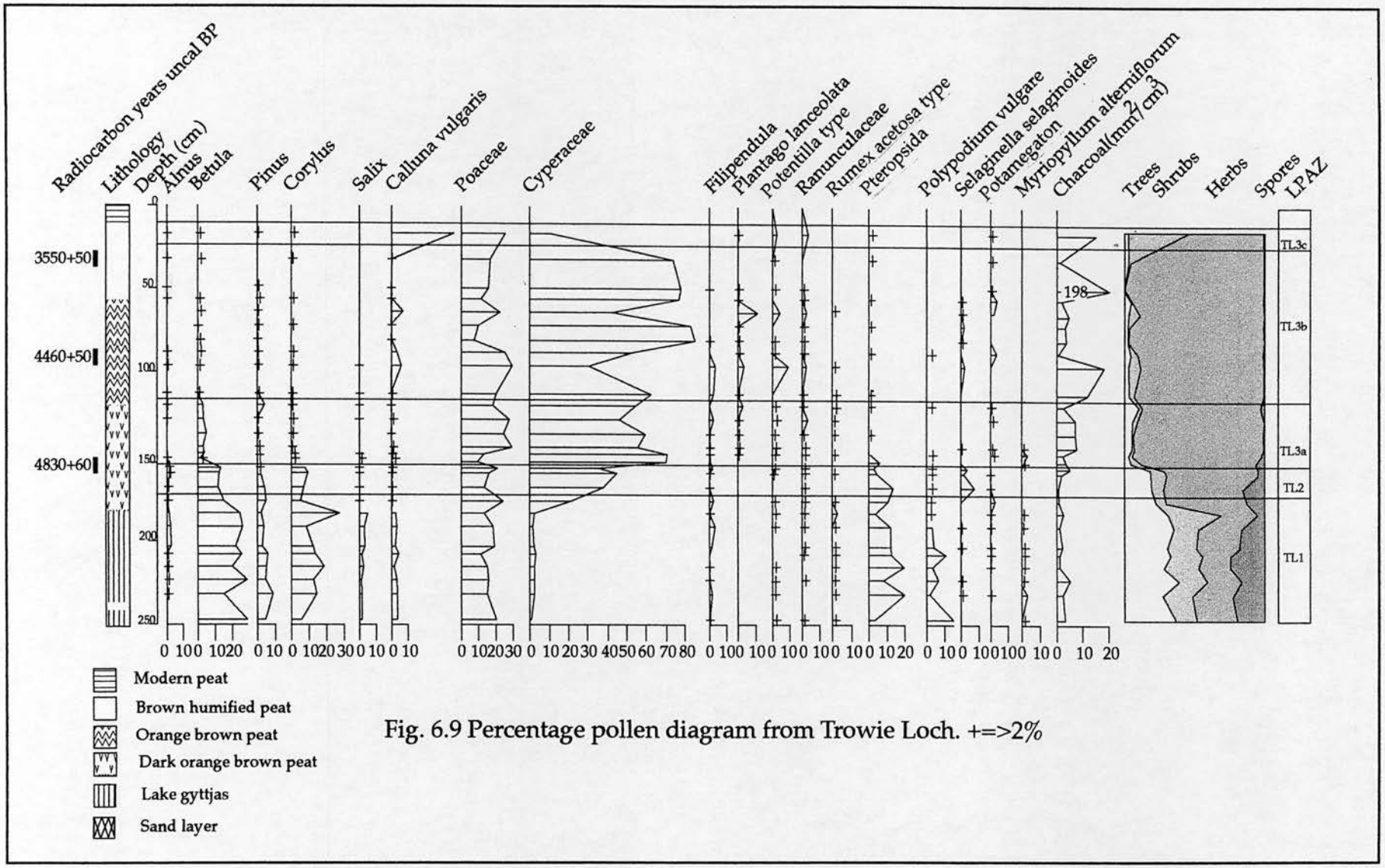


Fig. 6.9 Percentage pollen diagram from Trowie Loch. +=>2%

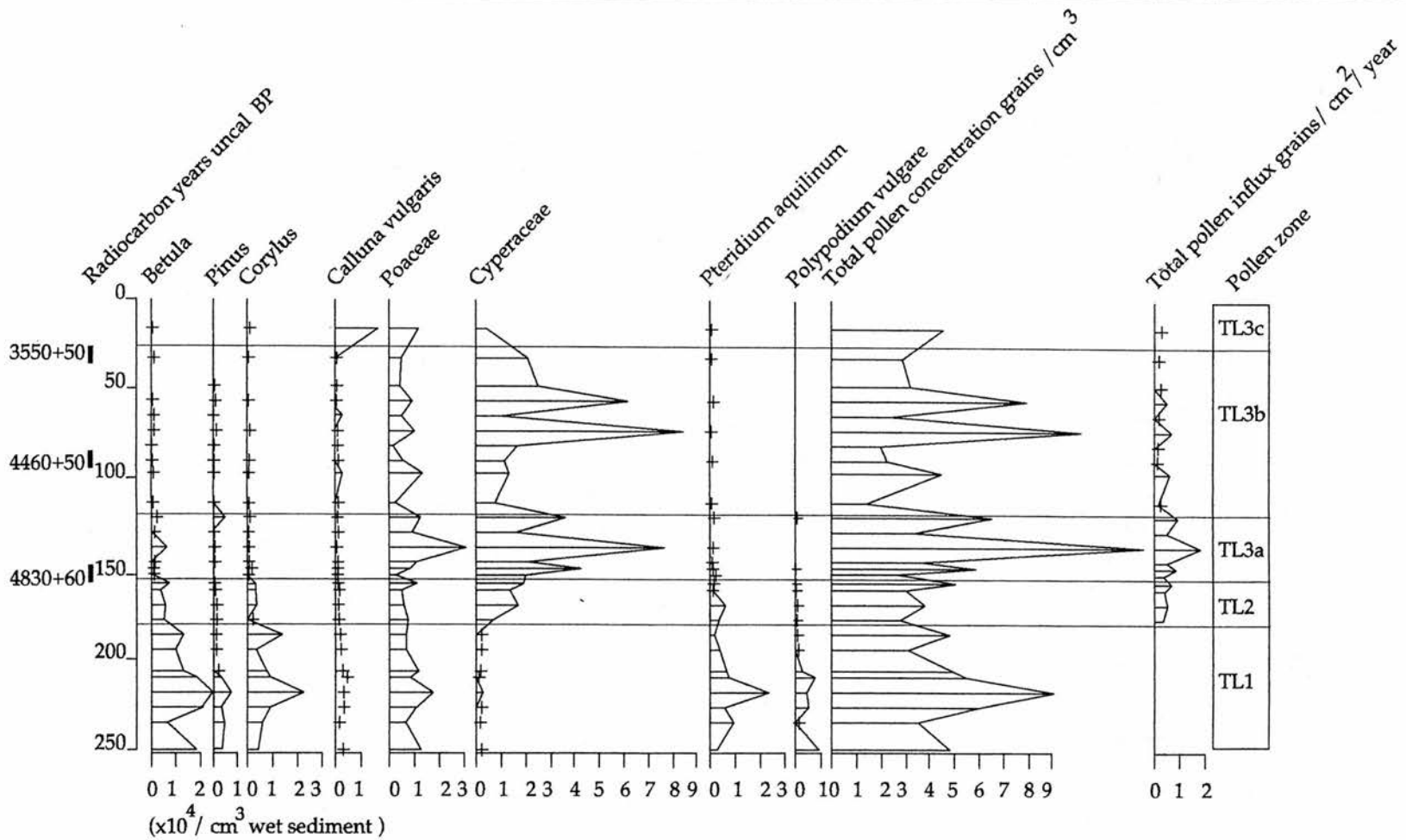


Fig. 6.10 Pollen concentration data from Trowie Loch

Depth(cm)	16	32	48	56	64	72	80	88	96	112	120	128	136	144	148	152	156	160	168	176	184	192	204	208	216	232	250
Quercus						1											1			1	1	2	2				
Ulmus											1				1				1		2		3	1	2		5
Juniperus																							1				
Empetrum																						2		4			3
Erica tetralix					2		1																				
Ericales undiff	5				1																						
Artemisia	1										3					1	1						1				
Alchemilla type												1	1							1		3					1
Caltha type														1	1	1	3				1						
Caryophyllaceae		1			1						2					1											
Cereal type	2											1		1													
Chenopodiaceae												1											1	1			
Asteraceae undiff.	1												2														
Asteraceae lactucoideae	1			2	2	1	1	4	2				1		1								2				3
Rubiaceae		1	1		1	1				1		2															
Glaux maritima																							1				
Lotus type														1	1								1	1			
Oxyria type	1										2				1		1		1								1
Plantago maritima	2				3	2			1	1	1			1	1						1	2	1		1		
Rhinanthus-type									1												1						
Rosaceae type					1				2	1			1							1				1			1
Rubus type												2															
Saxifraga oppositifolia-type												6															
Saxifraga stellaris-type																					1						
Stachys sylvatica	1		1						2																2		1
Succisa pratensis								1																			
Thalictrum	3																										
Apiaceae			1														2		1	1	1	1					
unknown		2	1						2											1		1	2				
Nymphaea alba																				1							
Myriophyllum spicatum															8	1					1	4	5	1			6
Isoetes																			1		4						
Nuphar																									3		1
Equisetum																		1									
Pteridium aquilinum									1					1						2							
Sphagnum	1	2			2							3	1	4				4				3	1	9	3		2

Table 6.6 Minor pollen taxa from Trowie Loch (n)

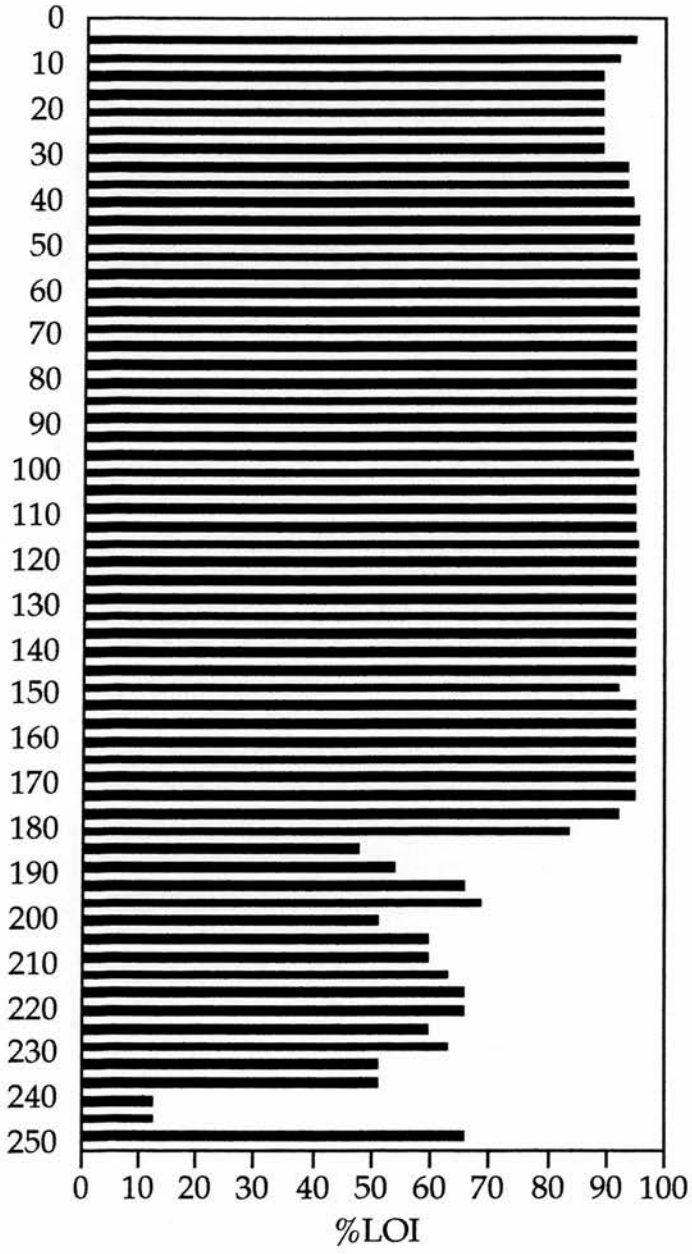


Fig. 6.11. Percentage loss on ignition for sediments from Trowie Loch

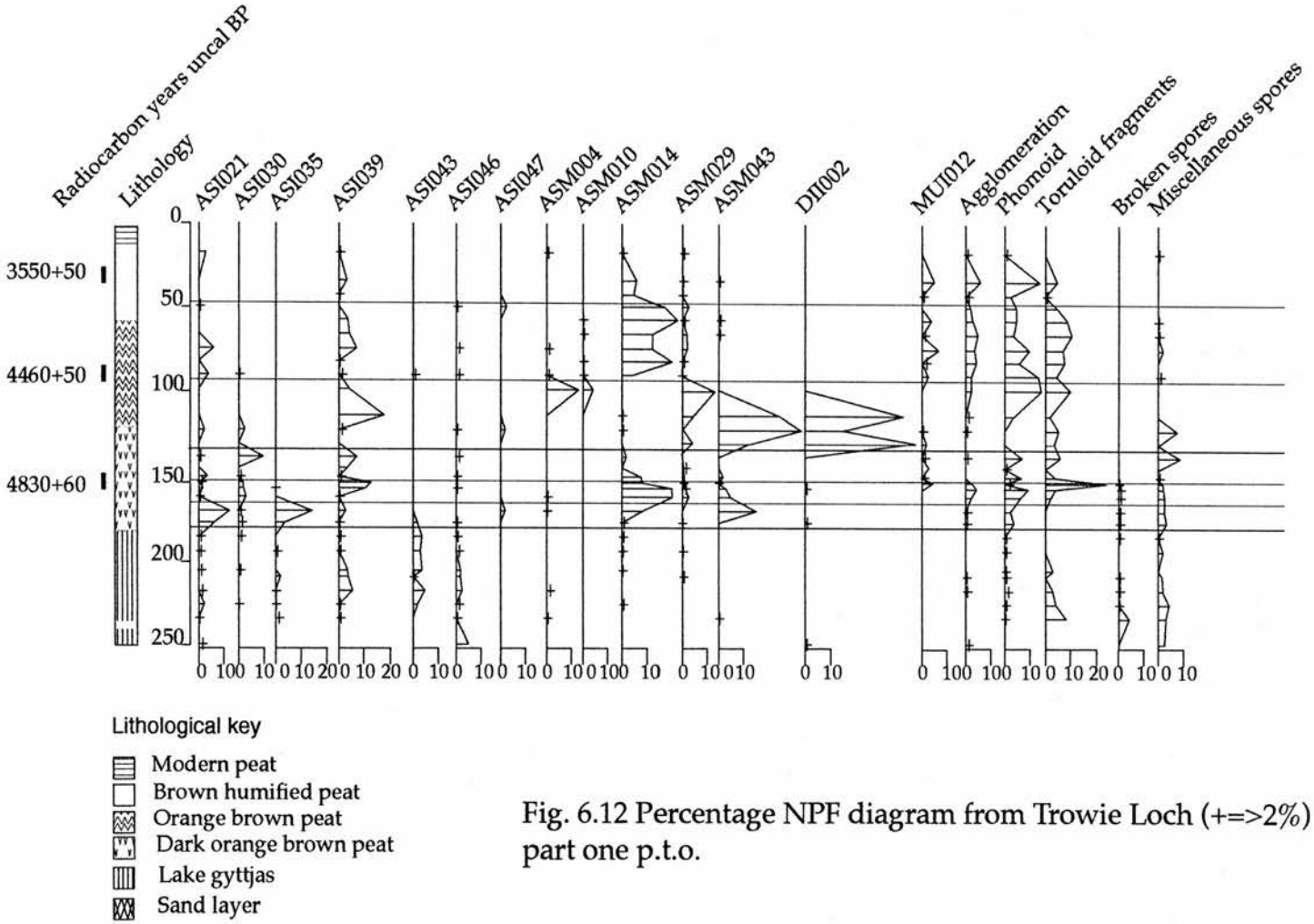


Fig. 6.12 Percentage NPF diagram from Trowie Loch (+=>2%) part one p.t.o.

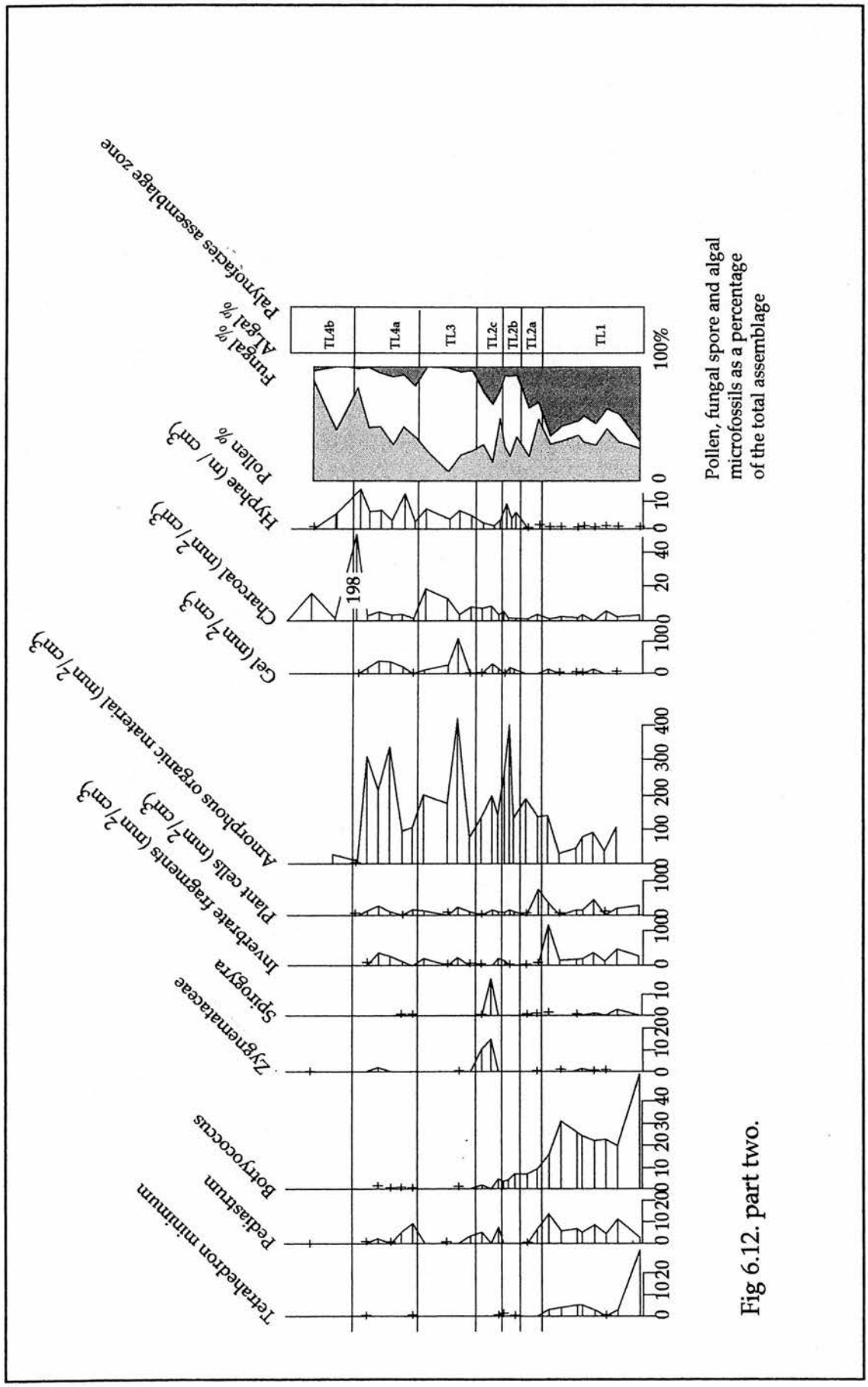


Fig 6.12. part two.

Depth	16	32	40	48	56	64	72	80	88	96	112	120	128	136	144	148	152	156	160	168	176	184	192	204	208	216	224	232	250
ASI010								1				1						13	1					1	3		1		
ASI026																													
ASI032													1		18														
ASI036		84						2							2														
ASI037		3			5	2		1							21														
ASI041																		1							1				
ASI042									21											1		4	2	2	4	4	8	5	6
ASI044																							4		21				
ASI045	1			1			4		8					3		1		3	3	5									
ASI048																1	3	5											
ASM003										2																			
ASM006																							1	1	3				
ASM016																													
ASM025												2								5									
ASM027		2	1																										
ASM028		5			7	25																							
ASM030				1			1					2				1	6	6				1	3						
ASM033																									1		1	6	
ASM035												6					3	6	12										
ASM037																												1	
ASM044																													
ASM045					1				1							1							6	2	1			3	
ASD002																													
ASD005							1								5										1				
ASP001										1																			
DII004																												1	
MOI001																					1								
MOI009							1		1	2																			
MOI010									1						5		1												
MOI011															8														
MUI004																											1		
MUI006											1				3														
MUI010									9												1								
MUI013		6	26		2	2																							
MUI016																		11	6										
TRI007															6														
IC006															23														
IC008																										1			
IC009																		1					2		4				
Gleotrichia																						48	3		2	3			
Sponge																						1	1	3					

Table 6.8 Minor fungal taxa from Trowie Loch

Fossil type	van Geel type	Clarke type (1994)	Specific type
ASI010	ASI014		Ampelomyces quisqualis (type)
ASI041	ASI020	T.207	Endogonaceae type
ASI045		T.35	
ASI046		T.72	Cladocera fragments
ASM003	ASI054	T. 169	Sordariaceae c.f. Tripterospora type
ASM004	ASD001	T.55	Chaetomium/Lophitricus type
ASM005	ASI054	T. 169	Sordariaceae c.f. Tripterospora type
ASM006		T.495	
ASM007		T.495	
ASM010		T.368	Sordariaceae c.f. Podospora type
ASM014		T.126	Gaeumannomyces type
ASM025		T.35	
ASM027		T.6	c.f. Coniochataeceae
ASM029			Sporomiella type
ASM043		T.4	Anthostomella fuegiana
MOI009	MOD001		
MUI004			Dichtyosporium spp.
MUI008		T.8	Mycrothyrium spp.
MUI012		T.201	
ASD002		T.55	Chaetomium/Lophitricus type
ASD005	ASD008	T.44	Xylariaceae spp.
ASI037		T.66	
ASI044		T.332C	Semi cells of the Desmidiaceae
ASI048		T.313F	Mougeotia spp.
ASM045		T.128	

Table 6.9. Fungal spore types from Trowie Loch and their comparitives

Discussion

Vegetation development within the Trowie Loch Basin

Early Middle Holocene: c. 9000 - c. 7000 uncal. BP (9000 uncal. BP-5800 BP

As discussed above, on the basis of the absence *Alnus* from the basal sediments it is assumed that sedimentation began prior to *c.* 8400 uncal. BP (Bennett *et al.* 1992). During this initial phase the dominant local vegetation around Trowie Loch was a mosaic of open scrub/woodland dominated by *Betula* and *Corylus*, with tall herb communities containing *Filipendula, Polypodium* and Pteropsida. The presence of disturbed ground in the catchment of the site is indicated by *Rumex acetosa* type whilst the frequency of *Calluna vulgaris* suggests that small patches of dry heath may have been forming on the high ground to the south of the sampling site. The lake appears to have been fringed by *Salix.*

A marine incursion (240-244 cm)

There is an abrupt change in sediment type at 240 cm from lake gyttjas to coarse sand and gravel. The band of sand and gravel is present from 240-244 cm in the core, and has been traced elsewhere within the basin (see above). This basin wide sand and gravel layer suggests an event of some size, which would appear to rule out local slope instability around the sampling location. There are several possible explanations for this sand layer; it may result from a large marine storm, a tsunami event or as a result of wind blown sand.

Wind blown sand has been proposed as an explanation of sand layers in sediments from the Orkney Islands e.g. Bunting 1996 at Loch of Torness at *c.* 8000 uncal. BP and also at *c.* 5000 uncal. BP at the Bay of Skaill (Keatinge and Dickson 1979). There are several factors which argue against an explanation based on wind blown sand for the sand layer at Trowie Loch; firstly the deposit contains unsorted coarse sand and gravel which suggests a high energy marine or water borne deposit rather than a wind event, secondly, there are no obvious sources of sand in the Trowie Loch area, the coastline by South Nesting (in common with much of the rest of the Mainland) is such that beach forming material (e.g. sand) is rapidly moved into deep water (Firth and Smith 1993).

The sand layer would appear to be consistent with a Tsunami deposit rather than a large storm surge. The deposit may be traced elsewhere in the lake sediments of the basin, which is also a phenomena associated with Tsunami deposits; Dawson (*et al.* 1988) consider that storm surges tend to produce small localized sand deposits. Further, the available evidence from Shetland suggests that prior to 5000 uncal. BP relative sea level was 9m lower than at the present day (Hoppe 1965),which indicates that a storm of considerable magnitude such as a Tsunami would have to have been responsible for the deposit.

Without absolute dating it is not possible to state with any certainty if the sand layer at Trowie Loch is derived from the second Storegga slide. However, the site is consistent with an emerging pattern of layers of coarse sand occurring in peat and lake sediments from coastal locations elsewhere on Shetland (*cf.* Smith 1993 a,b) that have been attributed to the second Storegga slide.

On the basis of the probability that this sand layer derived from the second Storegga slide the remaining deposits are tentatively thought to date from *c.* 7000 uncal. BP (*c.* 5800 BC) (Dawson, Long and Smith 1988).

Early Middle Holocene: 7000 - 5000 uncal. BP, 240-180 cm open woodland (LPAZ TL1)

Sedimentation of lake gyttjas recommenced at some indeterminate point after the deposition of the sand layer. The main change to the pollen spectra is the presence of small quantities of *Alnus* pollen. The low frequency of *Alnus* during this period reflects long distance transport of pollen or the regional presence of this tree (*Alnus* is thought to have been present at Dallican Water to the north (Bennett *et al.* 1992)), rather than its local presence. Woodland continued to be dominated by *Betula* and *Corylus* with *Salix* present in wet areas fringing the loch during this phase. Other tree and shrub pollen taxa (except Ericales) present in the diagram include *Alnus, Quercus, Pinus, Sorbus aucuparia, Ulmus* and *Juniperus*. Of these, *Sorbus aucuparia, Juniperus* and *Alnus*, are known either from their modern presence (*Sorbus aucuparia, Juniperus*) or through dated macrofossils (*Alnus)* to have been present on Shetland. *Quercus* is thought on palynological grounds to have been a minor component of woodland on Shetland. *Pinus* and *Ulmus* probably derive from long distance transport (Bennett and Sharp 1993).

Woodland is no longer present on Shetland (except for the plantation of largely non-native species at Kerigord (Spence 1979)), but fragments of tall herb vegetation have been located on isolated holms on lochs where they are inaccesible to grazing sheep (Spence 1979). This vegetation type typically contains *Filipendula ulmaria*, Apiaceae(*Angelica sylvestris*), and a variety of ferns and herbs. The *Betula -Corylus* scrub woodland indicated in the diagram is similar in composition, (except for the dominance of *Corylus*) to native woodland at Berriedale on Hoy, Orkney (Keatinge and Dickson 1979). Currently, there is no modern analogue woodland in the Northern Isles for the type of vegetation community found in the palaeoecological record of Shetland.

Other vegetation communities present in the basin at this time include: possibly a fringing carr of *Salix* and Cyperaceae; a small heathland component with *Juniperus, Calluna vulgaris* possibly on the exposed high ground of Gletness to the south and nearby maritime communities are indicated by *Plantago maritima*, Chenopodiaceae and *Glaux maritima* (Spence 1979).

Middle Holocene 5000-4830 uncal. BP (3800 -3600 BC) Mire and woodland (LPAZ TL2 180-150 cm)

With the final infilling of the sampling site and a change in sediment type from lake to mire peats there are a number of changes in the pollen record. Vegetation growing on the mire surface gradually comes to dominate the pollen record (Cyperaceae, Poaceae, *Potentilla* spp.). The local dominance of mire taxa does cause some interpretative difficulties for the subsequent analysis as many of the common pollen taxa identified may either originate on the mire surface itself (Cyperaceae, Poaceae, *Potentilla erecta* etc.) or be present in nearby vegetation communities (Scott and Palmer 1987, Moore, Webb and Collinson 1991).

Pre-clearance vegetation disturbance?

Before the initial clearance episode during LPAZ TL3 there is some evidence for slight disturbance of the vegetation during LPAZ TL1 and TL2 with declines in Pteropsida and *Polypodium* from 188 cm in TL1 and in *Filipendula* , Pteropsida and *Betula* at 160 and 168 cm in TL2.

Woodland clearance and recovery, LPAZ TL3a (154-112 cm) 4830- 4500 uncal BP (3600-3200 BC)

At the beginning of LPAZ TL3a clearance of woodland took place and declines occurred in the frequency of tree, shrub, tall herb pollen taxa and ferns. This is accompanied by a large increase in microcharcoal frequency, Cyperaceae pollen and the start of the continuous presence of *Plantago lanceolata.* The initial clearance episode is relatively short lived - at Trowie Loch it is approximately 100 years in duration (LPAZ TL3a).

After the initial expansion of Cyperaceae and the reduction of tree pollen there is a subsequent decline in Cyperaceae pollen during LPAZ TL3a, which is accompanied by a slight recovery in the values of *Betula* and *Filipendula* pollen. *Filipendula,* as well as being a mire plant, forms a part of the wider tall herb communities of Shetland (Spence 1979). As such it is often regarded by palynologists as a indicator of tall herb communities in the catchment (e.g. Keith-Lucas 1986, Johansen 1975). At Trowie Loch *Filipendula* pollen may therefore either be growing on the mire surface or in the wider catchment and care is needed in the interpretation of its pollen curve. The overwhelming dominance of Cyperaceae pollen obscures the detail of these changes, but the pollen concentration curve suggests that this is a real rather than an apparent recovery in *Betula* pollen. There is no associated recovery in other tree or shrub pollen taxa. The first appearance of a *Hordeum* type pollen grain occurs at 144 cm, which coincides with a rise in charcoal values. The steadily expanding charcoal curve and the presence of the cereal grain at 144 cm suggest that, as at Scord of Brouster (Keith-Lucas 1986), human activity was continued within the basin during woodland recovery.

Diagrams with evidence for woodland clearance in the fourth millennium BC, principally Trowie Loch, Scord of Brouster, Dallican Water, and probably Loch of Brunatwatt, have a common pattern of an initial clearance and recovery of woodland, followed by its subsequent extinction (Bennett *et al.* 1992, Edwards and Moss 1993, Keith-Lucas 1986). The timing of events varies considerably amongst these sites. The initial clearance, recovery and reclearance of woodland occurs very rapidly at Trowie Loch, over *c.*250-300 years. At Scord of Brouster the process from initial clearance to woodland extinction lasts approximately 400 years (Keith-Lucas 1986), whilst at Dallican water the whole process takes nearly 900 years. (Bennett *et al.* 1992). Somewhat unsurprisingly these sites show a wide range of land use history

after the initial clearance that clearly reflect local conditions and the local society. However, the above analyses show the advantage of pollen analysis in demonstrating variation in the exploitation of land and speed of settlement as it affected vegetation.

After clearance, vegetation in the basin appears to have been largely dominated by open grassy conditions as indicated by the presence of *Plantago lanceolata*, and Poaceae, with some scrubby *Betula* woodland.

The status of *Plantago lanceolata*

The presence of *Plantago lanceolata* appears to increase after *c.* 5000 uncal. BP (3800 cal. BC) at most pollen sites on Shetland. (Johansen (1976) considered that *Plantago lanceolata* arrived on Shetland as a result of transportation by incoming Neolithic populations. Whittington and Edwards (1993), following Walker's study of St. Kilda (1984), suggest that *Plantago lanceolata* may have formed part of the normal maritime plant community of Shetland (see also Scott and Palmer 1987).

Whatever the initial status of *Plantago lanceolata*, opportunities for its expansion greatly increased after the beginning of the fourth millennium BC on Shetland. The diagrams from Lang Lochs, Murraster, Trowie Loch, Scord of Brouster, Dallican Water, and Gunnister Water all indicate either the first presence or expansion of this taxa after *c.* 3800 cal. BC (Bennett *et al.* 1992, Bennett *et al.* 1993, Hulme and Shirriffs 1994, Johansen 1975, Keith-Lucas 1986). It is noticeable that *Plantago lanceolata* has a comparatively small frequency and appears late in the sequence at the relatively inland sites of Lang Lochs and Gunnister Water, suggesting both a preference for coastal grassland habitats and the late expansion of human activity into these inland catchments (Bennett *et al.* 1993, Hulme and Shirriffs 1994).

The record of *Plantago lanceolata* on Shetland indicates that it was a part of coastal plant communities prior to human impact in the Neolithic and that it subsequently expanded as a result of the expansion of grassland communities with increasing human activity.

Woodland extinction and mire taxa

Tree pollen declines to levels consistent with an origin from long distance transport after 116 cm during LPAZ TL3b, probably as a result of the loss of woodland cover due to continuous pressure on woodland for

fires, structural uses and grazing pressure (*cf.* Keith-Lucas 1986). During LPAZ TL3b the dominant vegetation within the catchment appears to be open grassy conditions in which woodland, scrub and tall herb communities are largely absent. This represents a largely similar landscape to that present at Trowie Loch today. One key difference from the present is the absence of any indication of blanket bog and acid heath communities during LPAZ TL3b. Intermittent increases in *Calluna vulgaris* pollen frequencies occur within the sub-zone which indicates some small areas of acid heath, probably on the high ground of Gletness to the South. But acid heaths and blanket bog appear to be a relatively late development within the Trowie Loch catchment.

Within the largely monotonous pollen record during LPAZ TL3 it is possible to identify a set of variations in the vegetation record that reflect local mire and basin wide vegetation change.

At the beginning of LPAZ TL3b there are increases in Poaceae pollen, *Calluna vulgaris, Plantago lanceolata, Ranunculus* type and *Potentilla* type. The expansion of *Potentilla* type reaches a maxima in the sample at 96 cm. *Potentilla* type, which may be either *P. erecta* or *P. palustris* but in this case probably *P. erecta* (Bennett *et al.* 1992), is associated with dry phases of blanket mires, and has been interpreted as indicating periods of intensive grazing of mire surfaces by Moore (1969) in (Moore, Evans, and Chater 1986). There is also a increase in the level of microcharcoal during the initial part of LPAZ TL3b which may indicate an increase in human activity in the vicinity of the mire. The dry phase indicated during the early part of LPAZ 3b, may also be due to autogenic changes within the mire leading to hummock formation, and the pollen changes discussed above (Moore and Bellamy 1974, Barber 1981).

The period of increased microcharcoal ends at 96 cm and from 88-70 cm during LPAZ TL3b there is an increase in Cyperaceae and reductions in *Plantago lanceolata* and Poaceae pollen and microcharcoal. This may either represent local changes to wetter pool conditions on the mire or it may be the result of a reduction in human activity. The lack of a recovery in tall herb taxa such as *Filipendula,* Umbellifereae, and *Pteropsida* during this interval suggests that grazing and associated human activity continued in the basin. The evidence indicates perhaps that the increase in Cyperaceae is the result of autogenic changes within the mire and that the high frequencies of

Cyperaceae are obscuring the record of vegetation change elsewhere in the basin.

At sample 64 cm there is another peak in *Plantago lanceolata, Plantago maritima, Potentilla* type and Poaceae pollen and a decline in Cyperaceae, as at 96 cm. This may reflect an expansion of pasture within the catchment or, it may be the result of local autogenic changes to drier conditions within the mire. During such dry hummocky phases pollen production of local Cyperaceae may decline allowing a larger amount of pollen rain from the basin to be deposited on the mire surface (Keith-Lucas 1986). Consequently, this apparent expansion in pasture may in fact merely represent changing pollen recruitment to the sediments of the mire with no associated vegetation change. Interestingly, there is no increase in microcharcoal levels to indicate an increase in human activity in this sample.

At 48 cm there is a large increase in microcharcoal levels dated to *c.* 2050 cal. BC which correlates well with the date for the base of the buried soil at South Nesting Hall of *c.* 2000 cal. BC (Dockrill, Bond and O'Connor 1998). This increase in microcharcoal frequency is not accompanied by any other vegetational changes.

In LPAZ TL3c there is a change to increased frequencies of *Calluna vulgaris* pollen indicating an increase in the amount of heathland taxa present either within the catchment or on the mire surface (Bunting 1994, Hulme and Shirriffs 1994). This increase in *Calluna vulgaris* is interpolated as occurring at *c.* 3200 uncal. BP (*c.* 1200 cal. BC). Whilst there is a spread of dates for the development of acid heath and blanket bog on Shetland the date from Trowie Loch is similar to the dates from Scord of Brouster (*c.* 3450 uncal. BP) (Keith-Lucas 1986), Dallican Water (*c.* 3120 uncal. BP), Gunnister Water (*c.* 2920 uncal. BP) (Bennett *et al.* 1992, 1993).

Local environmental change at Trowie Loch

Trowie Loch during the initial phase of LPfAZ TL1 appears to have been open fresh water as indicated by abundant blue green algae *Tetrahedron minimum* (van Geel *et al.* 1994), and *Myriophyllum alterniflorum* (Scott and Palmer 1987). The slopes surrounding the site may have been slightly unstable as there is some evidence of inwashed hyphae present in the core, and a relatively high inorganic content with percentage loss on ignition values at *c.* 60% (Fig 6.11).

After deposition of the sand layer (discussed above), lake sedimentation recommenced with increases in *Pediastrum* and *Botryococcus*. The presence of occasional pollen of *Myriophyllum spicatum* indicates alkaline water conditions (Scott and Palmer 1987). Occasional fossils of Zygnemataceae and *Spirogyra* and algal type ASI043 (Desmidiaceae) type were also located (van Geel *et al.* 1989). The presence of hyphal fragments and LOI percentage values suggest continuing low level input of minerogenic material into the lake probably, due to local soil instability and erosion, from the surrounding steep slopes.

The hydrological change from lake to mire conditions is most obviously demonstrated by the increase in Cyperaceae pollen at 176 cm which marks the boundary between LPAZ TL1 and TL2 and LPfAZ TL1 and TL2a. Increasing eutrophication of the shallow lake at 184 cm is indicated by the maxima in *Gleotrichia* type and increases in sponge spicules and *Spirogyra* type (LPfAZ1) (Round 1981, van Geel *et al.* 1989). There is a rapid decrease after 184 cm in most types of palynodebris except amorphous organic matter and charcoal which increase. Pollen and algal microfossils dominate the palynofacies assemblages of the lake deposits and pollen and fungal microfossils dominate during the the mire phase.

During the initial period of mire formation (LPfAZ TL2a) 178-164 cm) the continuous presence of algal taxa such as *Botryococcus* , ASI021 and ASI043, pollen from *Potomegaton* and low hyphal frequency values indicate that conditions were relatively wet, possibly with seasonal shallow pools (van Geel *et al.* 1989, Round 1981, Middeldorp 1982). The local presence of Cyperaceae during LPAZ TL2 is suggested by its high pollen representation and also by two fungal spore types associated by van Geel with Cyperaceous spp. hyphopodia of *Gaeumannomyces* type and spores of *Anthostomella fuegiana* type (types ASM014 and ASM043) (van Geel 1978, van Geel *et al.* 1988, Ellis and Ellis 1985). With the change to terrestrial conditions in LPfAZ TL2a the amount of invertebrate fragments and identifiable plant cells declines. Whether this is due to taphonomic changes affecting the preservation of these fossils or because of the change in habitat altering the species incorporated into the mire sediments or some combination of these and other factors is not clear.

The local mire conditions, as indicated by the non-pollen microfossils and palynofacies data, suggest that drier conditions prevailed during

LPfAZ TL2b (164-146 cm). Drier conditions on the mire surface during LPfAZ TL2b(164-146 cm) are indicated by the absence or reductions in algal types, and increases in fungal hyphal remains, and fungal remains (Middeldorp 1982, van Geel 1978). This drier period is followed during LPfAZ TL2c (146-134 cm) by wetter conditions, as indicated by the peaks of Zygnemataceae type and *Spirogyra* type at 144 cm which suggest that there was standing water, possibly seasonal pools, of probably eutrophic or stagnant water during this period (van Geel 1978, van Geel *et al.* 1988). Values of *Gaeumannomyces* type and *Anthostomella fuegiana* type decline during LPfAZ TL2c.

NPF changes associated with increases in *Plantago lanceolata*

The microfossil assemblage also changes at the time of the increase in *Plantago lanceolata* during LPAZ TL3a and LPfAZ TL2b. There is the first continuous presence of fungal spore taxa indicative of dung, cellulose decay and burning e.g. fungal type ASM029 (*Sporomiella* type, Ahmed and Cain 1972, Davis 1987, Watling 1992), and associated taxa such as Sordariacious form taxa ASM010 (*Podospora* type, van Geel *et al.* 1983) and fungal spore type ASM004 (*Chaetomium/Lophitrica* type, Clarke 1994). These taxa have been interpreted as indicative of cellulose decay, burning and dung (Ahmed and Cain 1972, Clarke 1994, Hawksworth *et al.* 1995, Lundqvist 1972), and in this case it is tempting to link their presence with the effects of grazing herbivores within the basin (Davis 1987). Fungal spore types ASM003, ASM010, ASM029 and ASM004 were also located at sampling sites with high dung frequencies in the Meldon Hills study.

After 128 cm in LPfAZ TL3 there is a abrupt change in the mire palynofacies and an increase in fungal spore *Anthostomella fuegiana* type (ASM043) and types DII002 and ASI039, and a decline in algal microfossils. This appears to be a dry phase within the mire between 128 cm and 96 cm which is associated with high levels of fungal microfossils, low levels of algal microfossils, and increases in amorphous organic material and hyphal frequencies (*cf.* Middeldorp 1982, van Geel *et al.* 1988, 1983 (a)). There are changes in the palynofacies assemblage at 96 cm with increases in microcharcoal, type ASM029 (*Sporomiella* type), ASM0003 (*Tripterospora* type) (Lundqvist 1972), ASM004 (*Chaetomium/Lophitrica* type), ASM010 (*Podospora* type), and declines in types associated with Cyperaceous taxa (ASM014, ASM043), and there is a slight increase in the amount of inorganic mineral

material within the mire sediments.

The sample at 96 cm marks the end of LPfAZ TL3 and dates to *c.* 4460 uncal. BP (3145-3019 cal. BC) and is interpreted as the end of a dry phase within the mire. The maxima in the sample at 96 cm of types ASM029 (*Sporomiella* type), ASM0003 (*Tripterospora* type) (Lundqvist 1972), ASM004 (*Chaetomium/Lophitrica* type), ASM010 (*Podospora* type) suggests that grazing was extended onto the mire surface, probably from an adjacent settlement. This dry phase is likely to be the result of autogenic change on the mire surface.

The date for the end of LPfAZ TL3 is earlier than that from the site at South Nesting Hall, which although undated is thought to date from the Bronze Age (Dockrill, Bond, and O'Connor 1998). A radiocarbon date from a buried soil associated with this site suggests that this soil began to accumulate in the Late Neolithic (3620 ± 55 uncal. BP, *c.* 2000 cal. BC). The sites responsible for the earlier phases of human activity at Trowie Loch are still therefore to be discovered, if they have survived.

The above period of dry mire conditions (LPfAZ TL3) and utilization of the mire surface for grazing is followed by a return to wet conditions after 96 cm during LPfAZ TL4a. Wetter conditions are indicated by the rise in algal microfossils, especially *Pediastrum* and *Botryococcus,* and a small increase in *Potomegaton* pollen, which suggests the presence of small pools of standing water on the mire surface (van Geel *et al.* 1988, Scott and Palmer 1987). This wet phase is accompanied by an increase in Cyperaceae values and also in ASM014 (*Gaeumannomyces* type) and a decline in herbaceous taxa. The charcoal curve drops to its lowest level since the onset of agriculture.

The decline in all types of palynodebris, and changes in the sediment lithology in LPfAZ TL4b after 54 cm suggests more humified conditions. The radiocarbon date of *c.* 3550 uncal. BP(1981-1742 cal. BC) at 35 cm indicates that the surface of the peat has been heavily cut over in the past. It appears that this cutting has affected peat preservation in LPfAZ TL4b. In this sub-zone there is the virtual disappearance of organic debris as a result of the decomposition of the top layers of peat. The decomposition of the peat does not appear to affect the pollen and non-pollen microfossil assemblage until after 32 cm. In the sample from 16 cm the microfossil assemblage is dominated by pollen and microcharcoal and most of the other types are

absent, probably as a result of biological and chemical breakdown of the peat.

Summary

Within the lake and peat deposits from Trowie Loch a number of environmental changes are present in both the pollen and palynofacies record from the site.

Sedimentation begins in lacustrine conditions some time in the early Holocene after the migration of *Corylus*, but before the migration of *Alnus*. This suggests a start date for sedimentation at *c.* 9000 uncal. BP (Bennett and Sharp 1993). At some point in the Holocene a *c.* 4cm thick layer of sand and gravel is deposited in the basin. Possibly, the Tsunami generated by the second Storegga slide at *c.* 7000 uncal. BP was responsible for the deposition of this layer (Dawson, Smith and Long 1988, 1990). Sedimentation of lake sediments resumes at some point after 7000 BP and the presence of algal taxa such *Tetrahedron minimum* and pollen of *Myriophyllum spicatum* indicate clear, possibly base rich, water (Scott and Palmer 1987, van Geel 1978). During the middle Holocene open woodland/scrub of birch and hazel became established in the vicinity of the loch, with an understorey of tall herb vegetation including *Filipendula* and Umbellifers and ferns such as *Polypodium.* Conditions in the lake and the surrounding vegetation appear to remain stable until the end of LPfAZ TL1, where there is a decline in ferns, *Polypodium*, and a large increase in *Corylus*, together with increasing eutrophication of the shallow lake as shown by increases in sponge spicules, *Gleotrichia* and *Spirogyra* type (van Geel *et al.* 1989, Round 1981).

With the onset of mire sedimentation, it becomes more difficult to follow extra-local changes in the catchment due to the high frequencies of locally derived Cyperaceae pollen. The presence of open woodland is indicated throughout LPAZ TL2 and there are several fluctuations in the curves of Pteropsida, which initially recovers and then declines. *Filipendula*, and *Betula* frequencies decline immediately prior to clearance at the start of LPAZ TL3a. During the mire phase the pollen and palynofacies record suggests that the surface went through a series of wet and dry phases.

Clearance of woodland and the expansion of grassland within the catchment is marked by declines in tree and shrub taxa in LPAZ TL3a and the beginning of a continuous curve of *Plantago lanceolata.* This is accompa-

nied by increases in the frequency and occurrence of fungal spore taxa such as ASM029 (*Sporomiella* type), ASM010 (*Podospora* type), ASM003 (*Tripterospora* type), and ASM004 (*Chaetomium/Lophitrica* type) which as discussed in Chapter 4 appear to be associated with the presence of grazing herbivores and increased dung frequency (see also Davis 1987, van Geel, Bohnke and Dee1981, Clarke 1994).

After woodland clearance there is evidence for a recovery in *Betula* pollen values before tree pollen values fall to levels consistent with long distance transport during LPAZ TL3b. After woodland extinction the vegetation record is dominated by local mire pollen but the pollen evidence also suggests that in the vicinity of the mire open grassy conditions dominated. During LPAZ TL3b there are changes to the mire palynofacies, pollen record and microcharcoal frequencies that indicate alterations to the local vegetation of the mire, differences in the level and type of human activity within the basin or some interaction of these.

In LPAZ TL3c, there is an increase in the frequency of *Calluna vulgaris* and a decline in Cyperaceae. This probably indicates the development of acid heath within the Trowie Loch catchment and possibly the growth of *Calluna vulgaris* on the mire surface. After 54 cm the palynofacies record becomes severely degraded with the loss of all types of palynodebris. By LPfAZ 4c only pollen microfossils are preserved in the preparations. This suggests that the deposit has been subjected to severe deterioration and humification. This finding would appear to concur with the evidence for truncation of the deposit by peat cutting and subsequent erosion and decomposition of the peat.

Interpretation

Interpretation of pollen records is prone to uncertainty because of the many competing influences that may effect vegetation. In this case there are four main areas of causation that may have acted independently or interacted to produce the observed vegetation and microfossil record at Trowie Loch. The four main factors that need to be considered are climate change, catastrophes such as tsumanis or possible volcanic effects, autogenic changes within the plants and soils of the catchment, and later the mire itself, and finally anthropogenic or other biotic factors (Bennett *et al.* 1992, Bunting 1994). In the following discussion the main features of the pollen diagram

will be discussed in relation to these four factors.

Climate change

As discussed in the introduction, climate modellers have stressed that apart from a period around *c.* 9000 uncal. BP when temperatures may have been *c.* 1°C warmer the remainder of the Holocene climate in the Atlantic region is thought to have been largely stable to the present day, with no significant long term variation in precipitation or wind speed (Kutzbach and Guetter 1986, Kutzbach *et al.* 1993, Briffa and Atkinson 1997). However, palaeoclimatology studies in Scotland are relatively undeveloped and several authors have suggested possible periods of climatic change that may have impacted on the vegetation of Shetland. In this discussion the main elements of debate are the effect of the climatic optimum *c.* 8000-6500 uncal. BP (Mayewski *et al.* 1996), and the Bronze Age cold/wet period *c.* 3000-2000 uncal. BP (Lamb 1977, Burgess 1985, Keith-Lucas 1986, Bunting 1994, 1996).

Bennett (*et al.* 1992, *et al.* 1993) for Shetland and Bunting for Orkney (1994, 1996) suggest that there is no evidence in the pollen data for a warm period during the supposed climatic optimum. Tipping (1996) has recently suggested that warmer and drier conditions did exist during a postulated warm phase from *c.* 8000- 6500 uncal. BP for the North Atlantic region the so called climatic optimum. Tipping suggests that the formation of dry acid heathland communities, which are more prone to spontaneous combustion as a result of lightning strikes, was encouraged by this dry period. It is these spontaneous combustions of natural vegetation that Tipping argues are responsible for the microcharcoal records.

Evidence from the Greenland ice cap summarized in Mayewski *et al.* 1996 suggest stable mild conditions from *c.* 9000- 6000 uncal. BP (Mayewski *et al.* 1996 p.80). Huntley and Prentice (1993) argue on the basis of widespread pollen records across Europe for slightly warmer conditions during the climatic optimum over northern and central Europe (p.149), but whether this warmer period affected the Northern Isles is not clear from the available data.

Pollen sites from the Northern Isles with microcharcoal records after *c.* 8000 uncal. BP such as Dallican Water, Gunnister Water, Loch of Brunatwatt, and Trowie Loch for Shetland and Keiths Bank, Quoyloo Meadow, Crudale Meadow, Loch of Knitchen and Loch of Torness, Orkney

do not demonstrate a consistent pattern of change in microcharcoal frequencies. An alternative hypothesis for microcharcoal records based on human activity from the period after *c.* 8000 uncal. BP is discussed below. Whilst the climatic optimum may have led to increased microcharcoal frequencies (see above) after *c.* 8000 uncal. BP there is currently insufficient evidence to demonstrate a definite climatic causation though this cannot be totally discounted.

A climatic origin for the onset of heath communities is often suggested (e.g. Keith Lucas (1986) and Butler (1998)). Climatic causes of blanket peat growth in the Northern Isles have received less attention in recent years due to the work of climate modellers (Kutzbach and Guetter 1986), which suggest a stable temperature regime for the later part of the Holocene. The period after *c.* 4000 uncal. BP and especially between *c.* 3000-2000 uncal. BP is often suggested as a period of colder, damper weather in Britain (Lamb 1977, Blackford 1993, Tipping 1994). Recent work summarized in Briffa and Atkinson (1997) including evidence from pine stumps, tree lines, climate response surfaces suggests a growing consensus "for deteriorating (i.e cooling and/or becoming wetter) conditions at or after 3000 uncal. BP" in Britain (Briffa and Atkinson 1997 p.101).

The development of heath and moor is a complex process occurring in response to shifts in the hydrological balance of soils leading to waterlogging, progressive loss of nutrients, and the development of a heath plant community able to exploit such impoverished soil conditions (Moore 1988). Several causal factors have been put forward, including climatic change, human interference and autogenic change (Moore 1988).

A climate shift leading to wetter and/or colder conditions is one factor than can lead to the shift from woodland or open grassy conditions to heath or blanket bog. Reductions in evapotranspiration lead to increased waterlogging of soils and the formation of heathland communities (Moore 1988, Godwin 1981). Conway (1948) drew attention to variations in the way that vegetation communities will react to any given climate change depending on local factors such as slope, soil type etc, and that a threshold leading to the formation of a heath community may be passed at one location but not at another. This would imply that one would not expect a synchronous response across a large area, but rather a spread of dates if climate change was leading to the expansion of blanket bog (Moore 1988).

Autogenic change may also lead to heath formation. For example, in generally wet climates precipitation may lead to nutrient loss and soil leaching and eventually the replacement of open woodland or tall herb communities by heath (Bennett *et al.* 1992, Johansen 1975). Autogenic change may be responsible for the early development of heath in areas such as Orkney (Bunting 1996), Northern Scotland (Pennington 1972), Shetland (Hulme and Shirriffs 1994), and the Faroes (Johansen 1975).

Human activities such as burning, grazing of animals, woodland removal for construction etc. all lead to the removal of woodland and this leads to a rise in soil water tables (Chambers 1988, Moore 1988). Burning of vegetation can reduce the permeability of soils due to blocking of pore spaces by fine charcoal particles (Mallik *et al.* 1984), which again can increase the amount of surface water.

In the Northern Isles and northern Scotland peat inception and the development of heathland communities appears to have begun from as early as the eighth millennium uncal. BP e.g. at Aukhorn (Robinson 1986), Loch of Winless *c.* 8400 uncal. BP (Peglar 1979), from *c.* 7000 uncal. BP at the Loch of Torness, Hoy, Orkney (Bunting 1996) and on Shetland from *c.* 7000 uncal. BP at Lang Lochs (Hulme and Shirriffs 1994), whilst at Scord of Brouster (Keith-Lucas 1986), Gunnister Water (Bennett *et al.* 1993), Dallican Water (Bennett *et al.* 1992) and Trowie Loch the increase in heathland taxa occurs between *c.* 4000-3000 uncal. BP. The widespread diachroneity in the development of heath and peat communities suggests that there is no common climatic cause. For Shetland, Bennett (1992) has argued that the diachronous nature of heathland expansion indicates that there was no climatic downturn after 4000 uncal. BP, and suggests instead that the interaction between the naturally wet climatic, local. edaphic conditions and human activity lead to the expansion of blanket bog and heathland. He points to the Faroes (Johansen 1975) where blanket bog initiation appears to have occurred due to autogenic changes, coupled with a wet climate.

A climatic cause for the onset of heathland cannot be completely discounted, however. As discussed above, a wide range of dates for the onset of extensive heathland are available, ranging from the eighth millennium uncal. BP. However, a pattern for the onset of heathland on Shetland is developing with several dates falling between 4000 and 3000 uncal. BP. For example, at Trowie Loch heathland expansion occurs at *c.* 3200 uncal. BP,

very similar to dates from Dallican Water (*c.* 3120 uncal. BP) (Bennett *et al.* 1992), Gunnister Water (*c.* 2920 uncal. BP) (Bennett *et al.* 1992, 1993), Scord of Brouster (*c.* 3450 uncal. BP) (Keith Lucas 1986) and Saxa vord, Unst (*c.* 3733 uncal. BP) (Edwards 1996). A similar date for the increase of heathland on Orkney e.g. Mid Hill, Orkney 3733 uncal. BP (Keatinge and Dickson 1979) is also known. This spread of fourth millennium uncal. BP dates from Shetland may suggest a worsening climate at this time. Further research is required into the palaeoclimate of the Northern Isles to confirm this developing pattern.

Autogenic change

The interaction of soils, weather and vegetation dynamics will ensure that even under constant climatic conditions changes to vegetation and landscape will occur. Shetland, with its largely acid igneous and metamorphic geology, and high precipitation demonstrates a natural tendency towards the formation of acid soils and acid loving vegetation communities (see Bennett and Sharp 1993, Spence 1979 and Hulme and Shirriffs 1994). The pollen and palynofacies record shows several possible instances of autogenic change, particularly in the mire sequence.

Prior to the change from lake to mire sediments there is a increase in *Corylus* and a decline in Pteropsida and *Polypodium* values. Possible causes for this change include increased closure of the woodland canopy preventing sporulation or dispersal of fern spores or perhaps some kind of anthropogenic activity such as the introduction of a grazing herbivore.

Similar pre-clearance disturbance of vegetation was reported at Scord of Brouster where an increase in *Corylus* is attributed to a phase of pre-clearance grazing at *c.* 5000 uncal. BP (Keith-Lucas 1986). At Trowie Loch the absence of an associated increase in microcharcoal levels coincident with the rise in *Corylus* and subsequent falls in Pteropsida, and *Polypodium* would tend to point to either an unaccompanied feral grazer, or some autogenic change in vegetation that favoured *Corylus* over the fern community. It may be possible that *Corylus* expanded within the woodland and that an increase in closed woodland or a denser *Corylus* dominated understorey led to declines in Pteropsida and other tall herb taxa. Bunting (1994) has found evidence of dense canopied *Betula - Corylus* woodland (also with high *Corylus type* frequencies) on Orkney during the mid-Holocene, it is a possibility that

similar dense canopied woodland may also have developed locally on Shetland.

Within the mire itself, a number of changes are indicated in the pollen and palynofacies record. The fluctuations in algal taxa, palynodebris, hyphal frequency, fungal spores and pollen taxa suggest that the mire underwent a series of wet and dry phases as outlined in the sections above. Keith-Lucas describes a similar set of wet/dry phases from the mire at Scord of Brouster, based on both pollen and macrofossil analysis (1986). Increased frequencies of algal microfossils, Cyperaceae pollen, occasional pollen from aquatics such as *Potomegaton* and decreases in hyphal frequency are interpreted as phases of wetter pool or channel conditions. Drier phases of hummocky vegetation are suggested by increases in Poaceae, *Calluna vulgaris* and *Potentilla* type pollen, along with increases in palynodebris and hyphal frequency and declines in the amounts of algal microfossils. Wetter periods tend to be characterized by reduced indications of human activity such as microcharcoal and *Plantago lanceolata* e.g. in LPfAZ TL4a. This may represent a real decline in human activity or it may be due to the swamping of the regional component by locally produced Cyperaceae pollen (*cf.* Keith-Lucas 1986).

There are three periods of dry conditions when Cyperaceae pollen is reduced and indicators of human activity rise, during LPAZ TL3b LPfAZ TL3, and LPfAZ TL4a. The interpretation of the apparent increases in human activity during dry phases is problematic. Is human activity really increasing or are the changes merely the result of an increase in the regional pollen component as a result of lowered Cyperaceae pollen production as suggested by Keith-Lucas (1986)? The increase in human activity suggested in LPfAZ TL3 is accompanied by a large increase in microcharcoal, increases in fungal spore types ASM029 (*Sporomiella* type), ASM010 (*Podospora* type) and ASM004 (*Chaetomium/Lophitrica* type) as well as increases in *Plantago lanceolata* and the presence of cereal pollen. In LPfAZ TL3 there evidence indicates that human activity was increasing in the vicinity of the mire.

During LPfAZ TL4 similar changes to those in LPfAZ TL3 occur; there is a decline in Cyperaceae pollen and increases in *Plantago lanceolata,* Poaceae etc. However, there is no associated increase in Sordariacious microfossils or in the microcharcoal curve. This suggests that in this interval an autogenic change to drier hummocky conditions is producing a better extra

local description of the vegetation in the Trowie Loch basin than would otherwise be available during a phase dominated by local Cyperaceae. Later in LPfAZ TL4 a large increase in microcharcoal frequency occurs probably associated with the clearance of the Hall site, no pollen changes are recorded in the mire at this point.

Once the switch from mire to lake sediments occurred, local pollen production by Cyperaceae dominates the pollen spectra. A cycle of hummock and pool development within the mire has been suggested based on the pollen, palynofacies and microfossil analysis. During dry phases pollen from regional sources increases whilst during wet phases local mire pollen dominates. This causes difficulty in the interpretation of human activity within the basin. By careful analysis of a range of microfossils it has been possible to interpret not just local mire changes but also to some extent extra-local changes in the vegetation and land use of the catchment.

Anthropogenic change

Human activity is widely held to have exercised a profound influence on the vegetation and landscape of Shetland (Spence 1979, Turner 1998, Bennett and Sharp 1993). The human influence has been to effect the removal of woodland and to maintain Shetland in its present unwooded form through the influence of grazing animals (Spence 1979). As discussed in the introduction it was hoped that the pollen and palynofacies analysis would provide some insight into human activity in the Trowie Loch basin during prehistory. The following discussion will consider the effects of human activity on vegetation during three key periods the Mesolithic, Neolithic and Bronze Age.

A Mesolithic interlude?

Defining the presence or absence of Mesolithic populations in the remoter parts of Scotland on the basis of the pollen record is an increasing preoccupation of pollen analysts (Edwards and Ralston 1984, Edwards 1990, Bennett *et al.* 1992, Edwards 1996, Tipping 1996, Moore 1996, Bunting 1996). The use of palynological proxies has now spread the Mesolithic colonization of Scotland to all but the remotest of Islands and many of these investigations are summarized in Edwards (1996). Archaeologists however, have not been able to locate the Mesolithic sites that would confirm the pollen records of possible Mesolithic activity (Edwards 1996, Turner 1998 (a)).

In the Northern Isles several sites have been put forward that appear to show charcoal records and vegetation changes consistent with Mesolithic interference. In order to evaluate the evidence from Trowie Loch for an absence of a Mesolithic human presence it is important to understand how these Mesolithic episodes are defined and what if any the alternative explanations for these events are.

Definitions of what constitutes anthropogenic interference with the vegetation of the Northern Isles during the Mesolithic period varies from author to author, as do the timing of these events. The main factor identified as indicative of human activity is an increase in the amount of microcharcoal particles in pollen diagrams (Edwards 1994, Moore 1996). At the four sites with palynologically described Mesolithic episodes; Dallican Water (Bennett *et al.* 1992, Loch of Brunatwatt (Edwards and Moss 1993) (both Mainland Shetland), Quoyloo Meadow (Bunting 1994) and Keiths Bank (Edwards 1996) (both Orkney), a number of differences in the response of vegetation coincident with increases in microcharcoal are described. At Dallican Water there is a prolonged period during which tree values remain unaffected whilst values of *Polypodium* and tall herbs decline and *Pteridium aquilinum*, *Calluna* , and Poaceae increase (Bennett *et al. 1992*). At Loch of Brunatwatt what is described as a temporary decline occurs in the frequencies of *Betula* and *Pteridium aquilinum* and there are corresponding increases in Poaceae and *Calluna* (Edwards and Moss 1993). At Quoyloo Meadow, Orkney, there is also a short lived decline in woodland taxa and an increase in Pteropsida and *Corylus* (Bunting 1994), whilst at Keiths Bank, Hoy there is a longer lived decline in *Betula* and *Polypodium* and an increase in *Calluna* and Poaceae (Edwards 1996).

If we closely examine the dates for a suggested anthropogenic presence during the Mesolithic of the Northern Isles they are also variable. At Loch of Brunatwatt the Mesolithic interference albeit undated, is described as "temporary" (Edwards and Moss 1993 p.128), whilst at Dallican Water the episode lasts from *c.* 7400 uncal. BP to 5400 uncal. BP (Bennett *et al.* 1992). On Hoy at Keiths Bank charcoal begins to increase at *c.* 6400 uncal. BP and ends at *c.* 5200 uncal. BP (Edwards 1996), whilst at Quoyloo Meadow Bunting sees a period of woodland decline lasting a few hundred years from *c.* 6500 uncal. BP (1994).

The observed palynological changes at the four sites are also

given different interpretations. At Dallican Water, Bennett *et al.* suggests that grazing by deer led to a decline in the tall herb vegetation and cooking fires led to the increases in charcoal frequency in the loch sediments (1992). At Keiths Bank, Hoy and Loch of Brunatwatt, Edwards considers the increases in charcoal to be due to either domestic fires or the clearance of woodland by fire but there is no mention of grazing affecting the vegetation (Edwards 1996, Edwards and Moss 1993 p.128). Bunting at Quoyloo Meadow interprets the increase in charcoal frequencies as a response to domestic fires and clearance but does not see any evidence for grazing (Bunting 1994 p.789).

From the above discussion it is possible to see that at each site the episodes of burning vary in duration, intensity, effect on the vegetation and interpretation of human behaviour.

In all of these sites the microcharcoal record is exclusively interpreted as a result of human activity and no other possible causation is considered. Two scholars have recently challenged solely human causation of fire events in the Scottish Mesolithic Moore, (1996) and Tipping 1996).

Moore (1996) has called into question Rackhams statement that "British woodlands (except pine) burn like wet asbestos" (Rackham 1986, p.79). Moore, points out that charcoal is simply the evidence of a fire and that by itself does not signify whether it was the result of a natural process or a human process (Moore p.64). Edwards and Ralston also note that charcoal may be found in pollen preparations from throughout the post glacial period where either because of the time period or location a human causation is likely to be absent (Edwards and Ralston 1984 p.25). Moore attempts to show that natural fires are highly variable in their cyclicity and severity and that simply equating increases in charcoal with human activity may be an oversimplification of a complex situation and that " ...moderate increase and steadily maintained levels of charcoal, with constant patterning in the pollen assemblage, are more informative as to human fire maintenance activity" (Moore 1996 p.72). Moore raises the intriguing possibility that "temporary" increases in microcharcoal may represent random fire events and that other more consistent evidence of human activity should be sought before a solely anthropogenic cause is accepted.

Tipping (1996) has also called into question the use of charcoal records as indicators of Mesolithic activity. He points out that during the period of the supposed climatic optimum, periods of aridity and the forma-

tion of acid heaths from *c.* 7000 uncal. BP on Orkney (Bunting 1996), *c.* 7500 uncal. BP (Bennett *et al.* 1992) at Dallican Water led to a rise in spontaneous natural fires. Tipping's hypothesis is intriguing but more work is needed on the palaeoclimatology of the Northern Isles to substantiate it.

Bennett's hypothesis of a supposed deer population on Shetland during the Mesolithic may be questioned by several new findings. Bennett suggests that this hypothetical deer population first flourished (and presumably spread throughout the Mainland) and then subsequently crashed and both the deer and the human population became extinct at *c.* 5400 uncal. BP. Bennett states that" if the above (deer) interpretation is correct, a similar sequence to that at Dallican Water ought to be visible at other places in Shetland" (Bennett *et al.* 1992 p.267). Since Bennett's work at Dallican Water several more sites have been analyzed; of these Gunnister Water (Bennett *et al.* 1993), Lang Lochs (Hulme and Shirriffs 1994) and Trowie Loch show no evidence either in their pollen or microcharcoal record of the changes seen at Dallican Water. The site at Loch of Brunatwatt despite a microcharcoal record indicative of human activity does not demonstrate similar vegetation changes to those at Dallican Water (Edwards and Moss 1993). The new pollen diagrams from Gunnister Water, Lang Lochs, Loch of Brunatwatt and Trowie Loch therefore do not indicate that grazing animals were affecting vegetation between *c.* 7400 and 5400 uncal. BP (Bennett *et al.* 1993, Hulme and Shirriffs 1994, Edwards and Moss 1993). Whilst there is some suggestion of pre-clearance vegetation disturbance at Trowie Loch and Scord of Brouster the estimated dates for this activity are during a period after which Bennett considers the Mainland of Shetland to be abandoned by human and herbivore populations (Bennett *et al.* 1992).

The number of pollen sites in the Northern Isles with microcharcoal records has increased considerably from one in 1992 to eight in 1999 (to the authors knowledge). Of these, four show some evidence for increased levels of microcharcoal during the Mesolithic Dallican Water (Bennett *et al.* 1992), Loch of Brunatwatt (Edwards and Moss 1993), Quoyloo Meadow (Bunting 1994) and Keiths Bank (Edwards 1996). The remainder do not indicate any Mesolithic human activity. As both Moore and Tipping point out there may be alternative explanations for increased microcharcoal frequencies ranging from occasional spontaneous fires (Moore 1996) to climatic driven changes leading to increased levels of natural fires (Tipping 1996).

The use of charcoal records as proxy indicators of human activity in the Mesolithic, should, in the authors view, be used cautiously and other possible causes should be explored before concluding a human causation for fire events. In light of the experience in the rest of Scotland the failure to find any Mesolithic artefacts on archaeological sites or during peat digging on both Orkney and Shetland (Armit 1996) is problematic for the pollen evidence of a Mesolithic presence on Orkney and Shetland. Until confirmation of the pollen evidence for Mesolithic activity is located in the form of artefacts and sites a solely human interpretation will remain a unproven hypothesis.

Woodland Clearance

Woodland clearance occurs at the start of LPAZ TL3a and is accompanied by an increase in microcharcoal and the start of a continuous curve of *Plantago lanceolata.* The cause of woodland decline is human activity associated with farming and settlement in the Neolithic *c.* 4830 uncal. BP (3721-3502 cal. BC).

Woodland clearance marks the start of LPAZ TL3a. The date for clearance (*c.* 4830 uncal. BP) is the earliest so far recorded for Shetland (see Table 6.1). However, it is within a similar date range to most dates from Shetland i.e the first half of the fourth millennium uncal. BP. If dates from Orkney are compared it appears that there is a slight lag in the colonization of Shetland by Neolithic settlers. Pollen clearance data suggests that farming commenced on Orkney *c.* 5100 uncal. BP (*c.* 3800 cal. BC) (Dickson 1994). Radiocarbon dates from the early settlement at Knap of Howar indicate occupation from *c.* 4770 uncal. BP (*c.* 3500 cal. BC) (Renfrew 1985) which is similar to the date from beneath a field boundary at Shurton Hill, near Lerwick (Whittington 1980), but earlier than those from the Scord of Brouster *c.* 4500 uncal. BP (*c.* 3200 cal. BC) (Whittle *et al.* 1986).

The pollen spectra from Dallican Water, Scord of Brouster and Trowie Loch as noted above contain evidence for regeneration phases after initial clearance (Bennett *et al.* 1992, Whittle *et al,* 1986). Keith-Lucas (1986) argued that this regeneration occurred while there was continued human activity in the catchment, whilst Bennett *et al.* (1992) considers that there was no anthropogenic activity in the basin during woodland regeneration. At Trowie Loch elevated microcharcoal values and the

presence of a cereal type grain during the regeneration phase suggests that the catchment was not completely abandoned at this time. The pollen data from Trowie Loch, Gunnister Water and Scord of Brouster implies that there was a shifting pattern of agriculture during the earlier part of the Neolithic (*cf.* Bradley 1978, Welinder 1983, Keith-Lucas 1986, Bennett *et al.* 1992).

Plaggen soils: a response to environmental deterioration or land shortage?

As discussed above one of the aims of the analysis was an attempt to identify any vegetation changes that may have occurred around the time of the adoption of intensive farming techniques, as typified by the presence of plaggen soils after *c.* 2000 cal. BC at South Nesting Hall. The pollen, palynofacies, and microcharcoal record all indicate human activity was occurring in the basin from *c.* 3600 cal. BC onwards. Whilst there is a period of lowered microcharcoal frequencies after *c.* 3000 BC for a period of two to three hundred years the failure of tall herb vegetation to regenerate suggests the continued presence of grazing animals in the site's catchment. At *c.* 2050 cal. BC (3550 ± 50 uncal. BP), at approximately the same period as the plaggen soil at South Nesting Hall began to accumulate (*c.* 2000 cal. BC, 3620 ± 55 uncal. BP), there is a increase in microcharcoal, which suggests clearance of land by burning, prior to settlement. There are few other indicators of human activity other than the charcoal curve for the subsequent period.

The evidence from Trowie Loch suggests that the development of a plaggen soil at South Nesting Hall was taking place during a period of largely open grassy conditions, after most of the woodland and tall herb communities in the catchment had been cleared. The use of infield agriculture and the subsequent development of plaggen soils is a particular phenomena of the Northern Isles (Davidson and Simpson 1994). Infield/outfield systems are a way for farmers to maintain soil fertility without having to move around the landscape when soils become exhausted (Welinder 1983). The reason why plaggen soils and infield/outfield systems develop are poorly understood but are usually described in terms of some form of environmental deterioration (Dockrill and Simpson 1994) or a combination of population pressure, arable land shortage and social factors (Dodgshon 1988).

If we consider that plaggen soil and infield/outfield agriculture may have been developing on Shetland from *c.* 2000 BC onwards at sites such as Tougs (Hedges 1986), Scord of Brouster (Whittle *et al.* 1986) and South Nesting Hall, can we then identify any of the factors driving this change? Dockrill and Simpson (1994) have argued that it is a response to podzolisation and falling soil fertility. The evidence from the pollen diagram both supports this hypothesis and provides a possible explanation for environmental deterioration.

Woodland taxa appear to have become locally extinct in the Trowie Loch basin some time before 3000 cal. BC, and the vegetation is subsequently dominated by taxa associated with grassland until the expansion of *Calluna vulgaris* at *c.* 1200 cal. BC.

The failure of woodland to regenerate after 3000 cal. BC was probably the result of continuous grazing pressure (Spence 1979). Spence has demonstrated by animal exclusion experiments that it would be possible to reintroduce woodland to Shetland if grazing pressures could be reduced, and further suggests that the present day tree line on Shetland should be around 200 m (Spence 1979). There is, therefore, no climatic, edaphic or ecological reason why tree populations should not re-establish themselves in the Trowie Loch catchment after 3000 cal. BC.

As Moore (1988) demonstrated, open grassy conditions and increased levels of grazing will act to deplete soil nutrients and to increase soil waterlogging, leading to soil podzolisation. Bennett (1992) suggested that the interaction of a generally wet climate, with open conditions at Dallican Water, inevitably lead to loss of soil nutrients. If we agree with Moore (1988) and Bennett *et al.* (1992), then the soils in the Trowie Loch catchment were undergoing systematic nutrient loss from *c.* 3000 cal. BC onwards. The continuing loss of soil nutrients as a result of the wet Shetland climate and continuous grazing after 3000 BC may have led to the environmental deterioration proposed by Dockrill and Simpson (1994). If agriculture was to be sustainable in the Trowie Loch area then some method of returning nutrients to the soil had to be found to maintain yields. The method that was developed was to augment soils with manure, seaweed etc. to maintain or even increase yields (Dockrill and Simpson 1994).

Environmental deterioration does not, however, explain why it was not possible to move settlements to as yet unoccupied areas within the

Mainland of Shetland. The evidence of pollen sites such as Dallican Water and Gunnister Water suggest that the catchments of both of these sites were unoccupied by humans after 3000 BC (Bennett *et al.* 1992, *et al.* 1993). With the available data it is only not possible to understand why settlement did not move away from areas of apparent environmental deterioration such as South Nesting (Dockrill, Bond and O'Connor 1998). This question requires further work on the archaeological record to understand the factors that tied ancient Shetlanders to the land.

Conclusion

This analysis was centred around two main questions: 1) Would the introduction of grazing herbivores affect mire palynofacies assemblages after the introduction of farming; 2) What effects did human activity have on the vegetation of the Trowie Loch catchment area.

Palynofacies and non-pollen microfossil analysis in the study of the cultural landscape

The results of the analysis are encouraging for the use of non-pollen microfossils in cultural landscape studies. The introduction of farming and the increase of *Plantago lanceolata* during the Neolithic is correlated with a rise in frequency of a number of fungal spore form taxa, principally ASM029 (*Sporomiella* type), ASM010 (*Podospora* type) , ASM004 (*Chaetomium/Lophitrica* type) and ASM003 (*Tripterospora* type) which are associated with dung, cellulose decomposition and burning (van Geel *et al.* 1981, 1983(a), 1994, Clarke 1994). The above fungal spore taxa were also present in samples with high dung frequencies from Meldon Hills (Chapter 4).

Further research is needed on these and other fungal spore form taxa to provide accurate identification to genus or family level. The results from Trowie Loch concur with those of Davis and van Geel (Davis 1987, van Geel *et al.* 1983, 1986, 1994) that fungal and algal taxa indicative of human economic activity are deposited in lake and mire sediments. The expansion of these taxa when correlated with pollen and loss on ignition data suggests that grazing was extended on to the mire surface at 96 cm. Mires are used in the present day agricultural economy of Shetland for grazing and hay production. Palynofacies and pollen analyses of wet meadows such as the important SSSI at Aith Voe may provide information necessary to the management of these important sites.

This study expands the work of van Geel on blanket mires and lake sediments in the Netherlands (van Geel *et al.* 1978, 1981, 1988) to include valley mires in the far north of Europe. The first pollen and microcharcoal evidence for human activity identified in the core consists of the reduction of tree pollen, Pteropsida spores and increase in microcharcoal and *Plantago lanceolata*, during the Neolithic at *c.* 3600 BC. The pollen evidence is accompanied by increases in a number of microfossil types that are also associated with animal dung, decaying cellulose and burning. This suggests that these microfossil taxa may be of use in confirming or providing further proxy evidence of human activity or herbivore impacts where perhaps no archaeological evidence is available This is to date the only such study carried out in the Northern Isles and other basins should be examined to provide confirmation of the correlation between the palynofacies and pollen record of human impact. However, both the pollen and palynofacies evidence from Trowie Loch indicates that there were no human or herbivore impacts (as defined by Bennett *et al.* 1992 p.267) in the samples examined from Trowie Loch prior to the Neolithic period.

The integrated study of non-pollen microfossils and palynodebris has been used to identify a series of wet/dry phases within the mire. Middeldorp (1982) first demonstrated a correlation between increased hyphal frequency and dry phases in peat sediments. At Trowie Loch there is evidence that increases in hyphal, gel and amorphous organic matter and declines in algal microfossil frequencies in peat may indicate dry mire conditions, whilst increases in algal microfossil and decreases in hyphal, gel and amorphous organic matter content indicate wetter mire conditions.

As well as possibly indicating wetter and drier phases on the mire, the palynodebris record strongly suggests that a breakdown of the peat structure occurred above *c.* 50 cm, probably as a result of drying and oxidation due to later peat cutting.

Pollen analysis

The pollen analysis has charted changes in the vegetation of the Trowie Loch catchment from *c.* 9000 uncal. BP to *c.* 3000 uncal. BP. Within this time span the deposition of a thick layer of sand occurred, probably as the result of a Tsunami around 7000 uncal. BP (5800 BC). Between 7000-5000 uncal. BP (*c.* 5800-3800 cal. BC) open woodland dominated by birch and

hazel with a tall herb understorey of *Filipendula,* ferns and Umbellifers was the main vegetation in the basin. Also present in the basin between 7000-5000 uncal. BP (*c.* 5800-3800 cal. BC) was heathland on exposed higher ground, and *Salix* and Cyperaceae communities fringing the lake. Despite the change to mire conditions after 180 cm, woodland continued to dominate the vegetation of the catchment until 150 cm, when the first clearance episode occurs at *c.* 4830 uncal. BP (*c.* 3600 cal. BC).

After clearance, local mire vegetation dominates the pollen spectra and wider vegetation changes within the basin are difficult to detect. Despite this, it is possible to identify five phases of change:

1) recovery of birch woodland between 150 and 116 cm

2) local extinction of woodland at approximately 4600 uncal. BP 116 cm

3) increases in *Potentilla* type, *Ranunculus spp.*type, *Plantago lanceolata* and Poaceae at 96 cm as a result of dry mire conditions and expansion of pasture onto mire surface

4) increase in *Potentilla* Ranunculaceae, *Plantago lanceolata* and Poaceae at 64 cm either as a result of expansion of pasture in basin, or as a result of changes within the mire

5) At 16 cm there is a increase in *Calluna vulgaris* indicating the expansion of heathland in the basin at *c.* 3200 uncal. BP (*c.* 1500 BC) possibly as a result of human impact and autogenic changes though a climatic deterioration may also be involved.

Unfortunately from the point of view of the wider study of the South Nesting landscape, the diagram is truncated at *c.* 1200 BC as a result of peat cutting (Dockrill, Bond, and O'Connor 1998). This is an occupational hazard for palynologists working from mire sediments in such a populated and fuel scarce landscape. The pollen analysis does show that activity was occurring in the Trowie Loch basin from the Neolithic period onwards, and it is tempting to suggest that the increase in charcoal at 48 cm is the result of clearance prior to the first phase of occupation at the Hall site. This certainly corresponds well with the early date from the buried soil at the Hall.

The archaeological evidence from survey and excavation at the Hall, and from the Scord of Brouster, and South Nesting suggests that the landscape of Shetland at least at a local scale, was comparatively well filled

by the Late Neolithic. The pollen diagram also supports the archaeological evidence that an economy including the cultivation of *Hordeum* within an infield system was practiced from the Late Neolithic onwards (Dockrill, Bond, and O'Connor 1998).

In general, the writer would suggest that use of palynofacies techniques in studies of the human landscape holds many advantages for the palynologist. As the soil pollen analyses at Balnuaran of Clava and the modern sampling studies at Meldon Hills have suggested increasing the range of microfossils analyzed may lead to better and firmer interpretations of past environmental and taphonomic change.

Chapter 7: Conclusion

Introduction

In this thesis I have investigated the contribution of palynofacies assemblages to archaeopalynology by analysing the microfossil content of a series of archaeological and other sediments. By using the technique in three different case studies as described in Chapters 4, 5 and 6, the advantages and disadvantages of palynofacies approaches were assessed. The thesis demonstrated that palynofacies analysis can contribute to an understanding of the taphonomic processes of archaeological deposits, and in the interpretation of the Cultural landscape. In the following discussion a restatement of the initial aims of the thesis is made. This is followed by a brief summary of the main findings of each case study. The next section then considers the contributions of the case studies to the original aims of the thesis. The penultimate section discusses the problems that arose during the course of the study and identifies problem areas with the application of palynofacies analysis to the study of archaeopalynology. The final section suggests directions in which future work would develop the technique of palynofacies analysis in Quaternary palaeoecology and archaeopalynology.

Aims of the thesis

Before summarizing the results of the case studies it is perhaps helpful to restate the aims of thesis.

1) to examine if microfossil palynofacies assemblages can provide interpretable environmental information.

2) to determine if microfossil palynofacies assemblages are indicators of macro and micro-environmental spatial variation.

3) to ascertain if changes in fossil palynofacies assemblages are associated with non-local environmental change (either vegetational or anthropogenic change)

Summary of the case studies

Meldon Hills

In this study of an upland sheep pen and its environs a number of surface samples were examined for their palynofacies content. The results

indicated a greater degree of heterogeneity in the fungal spore component of the assemblage than in the pollen component. For this environment it is thus hypothesized that fungal spore assemblages reflect environmental differences at a much smaller scale than do pollen assemblages. This result compares favourably with fungal ecological data that suggests similar small scale variation in fungal communities associated with different environmental conditions (Griffin 1972, Dix and Webster 1995). This study suggests that by integrating pollen and other non-pollen microfossils it should be possible to increase the resolution of palaeoenvironmental studies.

A further conclusion was that a series of fungal spores whose ecological preference is predominately dung (but are also found on rotting wood or burnt ground (Clarke 1994, Ahmed and Cain 1972, Lundquist 1972), were usually located in and around samples with high dung frequency. This finding as well as those from studies by van Geel *et al.* (1983), van der Wiel (1982), Davis (1987) and Clarke (1994), suggests that these spore types, with better taxonomic categorization may become useful indicators of dung and/or rotting vegetation in both archaeological and Quaternary studies.

Balnuaran of Clava

The palynofacies approach was very important for understanding not just environmental change but also the taphonomy of the sediments analysed in this case study. In particular, the distribution of fungal spores and fungal hyphae within and between the monuments strongly suggested that some later disturbance had affected the fungal spore content of soil deposits that were not sealed both laterally and vertically. This raised the issue of how to recognize later or even modern fungal spore material in archaeological deposits. In this study this was done through the use of assemblage data and the presence of unpigmented fungal hyphae (see also below).

Two chronological phases or periods were identified by the excavator at Balnuaran. The first period related to the construction of three Clava type cairns in the guardianship area at the beginning of the second millennium BC. The second period related to the construction of the small ring cairn outside the guardianship area and the reuse of the chamber of Balnuaran of Clava Southwest passage grave at the beginning of the first millennium BC.

Soil pollen analysis demonstrated that a range of vegetation types

existed at the monuments prior to their construction. This suggests that the spatial distribution of vegetation was perhaps more varied and complex than has been previously thought. Prior to the construction of the three large Clava cairns in the guardianship area at Balnuaran of Clava, the pollen evidence suggested a series of changes to the vegetation. Each cairn had been constructed in open conditions shortly after clearance. The nature of the cleared vegetation varied from cairn to cairn despite their proximity: at Balnuaran of Clava Northeast a mixed *Corylus-Betula* woodland was cleared; at Balnuaran of Clava Central and Balnuaran of Clava Southwest open grass and heath was burned to make way for the monument. The presence of cereal type pollen grains, weeds of cultivation and fungal spores associated with dung and cellulose decay beneath the core of the Central ring cairn possibly indicates some type of temporary occupation. The pollen evidence from the monuments indicates the cultivation of cereals, open areas of grassland/heath, either fallow or pasture, and more closed areas of scrub or forest prior to the construction of the Clava type cairns.

The evidence of vegetation change in the first millennium BC suggests that conditions had become more open but that heathland was not present in the vicinity of the cairn. The reuse of the chamber at Balnuaran of Clava Southwest for the deposition of a cremation deposit, is associated with burnt hazel pollen, suggesting that the cremation occurred in early spring when hazel is in flower.

Finally, the results of the analysis suggested that when selecting samples for AMS radiocarbon dating at Balnuaran, the results of the soil pollen analysis should be taken into consideration. At the Northeast passage grave the soil pollen analysis showed that secondary hazel dominated woodland or scrub had been burned prior to the monuments construction. AMS dating of a four fragments of hazel from this cairn all correlated within 50-60 radiocarbon years of each other. At the Central ring cairn the soil pollen analysis showed that an open grassy heath had been burned prior to the monuments construction. At this cairn three fragments of hazel were dated by the AMS method, though unfortunately these produced a diverse series of dates. If *Calluna vulgaris* fragments had been dated at this site it is proposed that a more coherent set of dates relating to the clearance phase would have been obtained. These results suggest that soil pollen analysis has an important role to play in understanding the dating of buried archaeological

soils.

Trowie Loch

The palynofacies analysis of the lake and mire deposits in the basin at Trowie Loch provided information relating to the local environment and basin wide environmental change.

Palynofacies analysis was used to gain information relating to the palaeoenvironment of the lake waters but also local changes to the mire surface, where cycles of wet channel or pool conditions interspersed with drier hummocky periods were identified. Several changes to the pollen spectra occurred during the mire phase but by using a palynofacies approach it was possible to determine whether these related to local fluctuations of vegetation on the mire surface or were the result of environmental variation within the catchment of the basin.

The analysis had several important findings about anthropogenic activity in the Trowie Loch basin and the use of non-pollen microfossils in the analysis of landscape history. Mesolithic activity as defined by Bennett *et al.* (1992) was absent in the Trowie Loch basin. The evidence from pollen analysis at Trowie Loch and elsewhere (Scord of Brouster, Gunnister Water (Keith-Lucas 1986, Bennett *et al.* 1993)) suggests that whilst there may have been a Mesolithic presence on Shetland, the first convincing evidence of human activity occurs at *c.* 3600 cal BC, when the initial clearance of woodland occurs and there is the start of a continuous curve of *Plantago lanceolata*, accompanied by increases in fungal spore types associated with herbivore dung, burning and vegetation decomposition. Woodland underwent a recovery phase before finally becoming extinct in the basin around 3000 cal BC. After the extinction of woodland, the vegetation was dominated by open grassy conditions until *c.* 1500 cal BC when there is some evidence for an expansion of *Calluna* dominated heath in the basin.

The vegetation history therefore suggests that increased grazing pressure after *c.* 3000 BC led to the extinction of woodland and its subsequent failure to regenerate. It is argued that this prolonged period of open conditions would have led to loss of soil nutrients, increased water tables and increasing soil podzolisation (Moore 1988). Decreasing levels of soil nutrients and increasing podzolisation would also have led to declines in both arable and pastoral yields, and an increase in environmental deteriora-

tion (Dockrill and Simpson 1994). In order to maintain or improve yields a system of plaggen soil agriculture and, by implication, infield/outfield agriculture developed some time between 3000-2000 BC (Dockrill and Simpson 1994). It is tempting but impossible to demonstrate that the start of the infield/outfield system dates to the expansion of grazing at *c.* 3000 BC.

In all of the case studies therefore, the use of palynofacies analysis was found to have enhanced the overall findings. The following section examines how the results of the case studies contributed to the aims of the thesis.

To examine if microfossil palynofacies assemblages can provide interpretable environmental information

- In most cases it is possible to interpret palynofacies assemblages in terms of the past environment using the presence of indicator species, from pollen, fungal spores and algal microfossils
- For samples where there are few identifiable microfossils it may be necessary to use statistical methods to interpret the overall assemblage
- Using both of the these methods it was possible to use the palynofacies data to produce useful environmental reconstructions

Using the palynofacies assemblages it was possible to use to produce environmental interpretations. The detail of the interpretations varied, however, depending on the class of microfossils used and the degree of ecological information available relating to a microfossil type. For example, it was possible to interpret the pollen data within the limitations of that technique, as outlined by Birks and Birks (1980), Faegri and Iversen (1989), Dimbleby (1985), Aaby (1983) and Edwards (1979). Interpretation of the other components of the palynofacies assemblages (fungal spores, algal microfossils and palynodebris), in environmental terms was more problematic.

In this thesis two approaches to environmental interpretation using non-pollen microfossils were employed; firstly the use of indicator species and secondly an assemblage approach (Clarke 1994, Galliard *et al.* 1992). For the indicator species approach, it is necessary to identify the fungal spore or algal microfossil to species, genus or family and to know its range of ecological variation, which it was possible to do for *c.* 25-33 % of the

microfossils. The assemblage approach relies on analysing statistical differences in the non-pollen microfossil content between samples (Birks and Gordon 1985, Clarke 1994). Unlike pollen analysis where almost all the microfossils are identifiable to species, genus or family level, other groups of microfossils such as Cyanophyta and fungal spores cannot presently be identified other than to type (van Geel 1994, Clarke 1994). This study and those by van Geel and Clarke suggest that anything between 5 and 40 % of non-pollen microfossils in a set of samples are identifiable to species, genus or family (van Geel 1978, Clarke 1994). In some of the case studies especially Balnuaran of Clava the large number of fungal microfossils only identified to type was problematic, as almost by definition no ecological information is available for these types. Some authors (Clarke 1994, van Geel 1978) have tried to use the context of a microfossil type as a proxy of its environmental preferences, but this is fraught with difficulties as there is an obvious danger of circularity. Only through more taxonomic studies will the problem of identification of fungal spores be overcome.

At most of the sites examined use, was made of indicator species to provide environmental information e.g. the use of the fungal spore *Sporomiella* type (ASM029) as an indicator of herbivore dung in Chapters 4, 5, and 6 (Ahmed and Cain 1972, Davis 1987). This methodology is useful where indicator species are present and their taxonomy and distribution is reasonably well understood. I have compiled all the presently identified fungal spore types in both van Geel's and Clarke's studies in Appendix 7, and provided an outline key to these microfossils in Appendix 10. Presently, there are approximately 130 identified fungal spores, of which about 60% are useful indicators of some form of environmental variation. Where present, therefore, fungal spores and identifiable algal microfossils can be important indicators of environmental variation.

A major difficulty is encountered at sites where unidentifiable non-pollen microfossils are in the majority, e.g. at Balnuaran of Clava (Chapter 5), where sometimes less than 5% of fungal spores were identifiable to a biological taxon. In such cases other routes to interpretation are needed.

At Meldon Hills (Chapter 4) and Balnuaran of Clava (Chapter 5) statistical analysis of non-pollen microfossils assemblages was used to identify patterns in the data. At Meldon Hills, this suggested an association between a number of fungal spore types and areas of high sheep dung fre-

quency. The situation at Balnuaran of Clava was more complex but it was possible to identify a suite of fungal spore types (or facies) that were associated with distinct depositional environments. One group was interpreted as representing the effects of post depositional biological disturbance and the presence of a intrusive fungal spore community; a second group was associated with either/or burning or strongly podzolic soils; a third group was tentatively associated with bioturbated acid soils. By combining both indicator species and assemblage approaches to non-pollen microfossil data it is possible to produce broad environmental interpretations. Better understanding of fungal spore taxonomy should lead to more refined environmental interpretations.

The thesis has showed that at present levels of knowledge, environmental reconstruction using palynofacies data is not consistent across differing types of environments and between different classes in the assemblage. In lake sediments and mires, where more research has been conducted, a large number of algal and fungal microfossils are identifiable to species, genus and family level. Within these depositional environments it is therefore possible to secure a reasonable environmental interpretations for the effort expended. For other environments, such as buried soils and archaeological deposits, little is known of their non-pollen microfossil content. This reduces the level of interpretation, as so few microfossils can be identified to anything other than type. In such deposits it is, however, possible to use assemblage approaches to the data to produce broad categories of interpretation, but these are limited in scope.

Are microfossil palynofacies assemblages indicative of macro and micro-environmental spatial variation

- Pollen, fungal spores and algal microfossils found to be best indicators of macroenvironmental variation
- Fungal spores were found to indicate environmental variation at scales of less than a metre. Pollen not as sensitive to small scale environmental variation

The most important component for identifying macro-environmental variation was found to be the pollen and spore component. As the use of pollen analysis as an indicator of environmental variation has been extensively considered in depth elsewhere (Birks and Birks 1980, Fægri and

Iversen 1989, Bergland 1986), its role in a palynofacies analysis will not be extensively discussed below. The use of pollen and spores was best seen at Trowie Loch basin (Chapter 6) where information on basin wide changes in vegetation were identified. Vegetation change at a more local scale was also identified in the pollen record at both Meldon Hills and Balnuaran of Clava (Chapters 4 and 5).

Other components of the palynofacies assemblage were also found to contribute to the study of macroenvironmental change. The presence of fungal hyphae in lakes was found to be a proxy record of erosion in lakes as described by Cushing (1964, *cf.*. Chapter 6). In the lake and mire sediments at Trowie Loch the presence of blue green algae and Cyanophyta allows some indication of water quality and nutrient status (Round 1981, van den Hoek *et al.* 1995, van Geel *et al.* 1994).

The role of fungal spores as a proxy indicator of macroenvironmental change is less clear. From this study and others such as van Geel's (1978) and Clarke's (1994), it appears that most fungal spore production occurs "*in-situ*" in peats and soils, etc. (Dix and Webster 1995), and that the contribution of transported fungal spores is negligible. An example of this is the low levels of fungal spores in the lake sediments at Trowie Loch which in comparison with fungal spore levels in peats and soils are very low (*cf.*. van Geel *et al.* 1988). Therefore, although the contribution of fungal spores to the air flora is immense (Ingold 1965, 1971), it appears that the contribution of transported spores to the overall assemblage is difficult to recognize (van Geel 1978, Clarke 1994). An example of macroenvironmental change being identified in the fungal spore record as the result of spore transportation is the increase in Sordariacious spores after the arrival of both human and herbivore populations at *c.* 3600 cal BC at Trowie Loch, Shetland (Chapter 6). These spores must have been transported either by air or by animal activity onto the mire surface where they were subsequently incorporated into the peat.

Similar statements may also be made in regard to palynodebris which, with the exception of microcharcoal, would appear to derive from local sources such as decaying plant material. This is because most palynodebris derives from cellulose, lignin or chitinous materials, and would therefore not be expected to be transported by air long distances to peat or soil sediments (Traverse 1988). In water based systems such as lake, stream

and marine systems, organic palynodebris may be transported long distances before being sedimented (Cross *et al.* 1966). At Trowie Loch in the lake sediments there appeared to be little contribution from terrestrially sourced palynodebris. The exception to this was microcharcoal, which as a chemically inert material is virtually indestructible to all but mechanical destruction (Tolonen 1986, Traverse 1988). This material can be transported long distances through both air and water- based systems before being deposited (Tolonen 1986, Traverse 1988). In this study, the presence of microcharcoal was used to describe both *in-situ* burning for clearance at Balnuaran of Clava (Locations A, E, D *cf.*. Chapter 5) and also for non-local burning e.g. at Trowie Loch, where burning in the surrounding area led to the deposition of microcharcoal in the mire sediments (Chapter 6).

Therefore, the palynofacies approach allowed the identification of macroenvironmental variation through the use of pollen, algal microfossils, fungal spores and microcharcoal analysis of a range of sediment types (lake gyttjas, buried soils, mire peats). Greater taphonomic and ecological emphasis on non-pollen microfossils should provide much more informed analyses of palaeoenvironments than are currently available. In this respect, the results are similar to those of studies carried out at the Hugo de Vries Institute by van Geel and his colleagues (e.g. 1978, 1981, 1983, 1988).

Palynofacies analysis by incorporating the analysis of fungal spores, hyphae and palynodebris into pollen analysis, appears on the evidence of Balnuaran of Clava and Meldon Hills to be able to identify different environmental conditions at scales of less than a metre.

The three case studies indicate that study of microenvironmental variation is where the techniques strength lies. At Balnuaran of Clava (Chapter 5) for example, variation in the fungal spore and hyphal assemblages, between closely spaced sampling locations was the result of post depositional changes to samples. These post depositional changes to the deposits would not have been identifiable other than through the analysis of fungal spores. The result from Balnuaran of Clava is consistent with those from other studies of sub-fossil fungal spore distributions such as that at Meldon Hills (Chapter 4), where fungal spore assemblages appear to vary markedly from location to location and studies by Clarke (1994). It also concurs with the findings of fungal ecology, where highly distinctive fungal spore communities (albeit with a wide range of variation at sampling loca-

tions) are known to be associated with certain defined environments, e.g. beech forest, grassland etc. (Griffin 1972, Dix and Webster 1995). Some of the variation identified in the assemblages from Trowie Loch, was clearly related to local microenvironmental change, but due to the lack of identifiable microfossils, it was difficult to interpret this variation except at a crude level (*cf.*. van Geel 1978).

The role of palynodebris in identifying microenvironmental variation is not clear. In some locations e.g. at Balnuaran of Clava, variation in fungal hyphae, brown carbonized material and phytoliths suggest that microenvironmental variation in palynodebris may prove to be important. However, the study of palynodebris in terrestrial sediments is in its infancy and all the results from this thesis from the analysis of palynodebris can only be tentatively interpreted.

To ascertain if changes in fossil palynofacies assemblages are associated with non-local environmental change vegetational or anthropogenic change

- By combining many different types of microfossil evidence it was possible to demonstrate that changes in palynofacies assemblages were the result of non-local environmental change particularly at Trowie Loch.

This research has demonstrated that palynofacies analysis can identify non-local environmental variation. At both Balnuaran of Clava and Trowie Loch non-local vegetation and anthropogenic change was identified by the use of palynofacies assemblages. At Trowie Loch changes to the pollen and non-pollen microfossil spectra were interpreted as indicating anthropogenic activity affecting vegetation e.g. the loss of woodland due to human and animal activity at *c.* 3000 BC. At Balnuaran of Clava, soil acidification was recognized through the development of heath vegetation prior to the construction of the Central ring cairn, and South-west passage grave.

In general it is possible to say that palynofacies assemblage data, by examining a broad range of microfossil types, can contribute to a understanding of extra-local environmental change. This is seen particularly at Trowie Loch where a range of microfossils, including algal, pollen, spore, fungal spore were used to identify basin wide changes invegetation, water quality, frequency of burning, herbivore impacts etc. But, as with pollen sam-

pling locations, the type of sampling environment will affect the degree to which non-local environmental changes will be recognized in the palynofacies assemblage (Berglund 1986).

With some qualifications it is possible to say that the results of the case studies have demonstrated the aims of the thesis. These qualifications will be discussed more fully in the critique section below.

Critique

As with any new type of study a number of central problems were identified with the methods used. These principally relate to the study of fungal spores in Quaternary palaeoecology and the key points are bulleted below.

- problems were encountered in relocating type microfossil due to the use of Silicone oil as a mounting medium
- some microfossils are present in such low frequencies that a cut off point for recording new types had to be introduced
- some classification problems were encountered with Clarke's (1994) recording scheme
- the lack of key's to fossil fungal spores and other microfossil types caused problems with identification
- the absence of a methodology for identifying microfossil types to species or genus.
- lack of taphonomic and distribution evidence for fungal spores

The recording of microfossils was hampered by the use of Silicone oil as a mounting medium. The viscosity of Silicone oil used in this study was 12,500cs, and on several occasions when returning to record and photograph microfossils after counting, they would often be difficult relocate having moved due to the fluid nature of the Silicone oil. Van Geel for this reason tends to use glycerine jelly to mount slides (personal communication). For this reason I would recommend splitting samples and mounting one half in glycerine jelly to provide type material, and the second in Silicone oil for routine counting, because the ability to rotate microfossils is an important aid in identification.

Occasionally, some new spore types would identified in low fre-

quencies in a single sample. In general if a new spore type was only present in a single sample and less than five in total were counted, then it would be counted as a miscellaneous spore type and not recorded as a specific type. In accord with both Clarke (1994) and van Geel (1978), such a cut off was found to be necessary to avoid using large amounts of time in the recording of rare microfossils.

Clarke's recording scheme, which while not without it's advantage' s was found in this study to be cumbersome and difficult to operate. This as yet unpublished method was specifically designed in the archaeology department at Edinburgh to classify unknown fungal spores (Clarke 1994). However, the principal objection to Clarke's scheme is that fungal spores from the same species may be morphologically diverse and individuals from the same species may be classified to different types. This principally results from the use of septal number as part of the classification. Septal number in many species, genera and families is highly variable e.g. *Bactrodesmium* spp. (Ellis and Ellis 1985). For example, at Balnuaran of Clava, where a number of morphologically similar spores have been grouped into three different classes and six different microfossil types using the Clarke scheme when in all probability they represent morphological variation in a single species. A further example is van Geel's type 10 (1978) which would in Clarke's (1994) scheme form be subdivided into four or more microfossil types.

In practice, Clarke's method of typing fungal microfossils does not confer any advantages over van Geel's type method. In fact it may obscure similarities between spores, due to their inherent variation. Further, it is complex and cumbersome to use and remember. For future work, using fungal microfossils, I would recommend the use of van Geel's type number system, until such time as a biologically based key to fossil fungal spores becomes available. Van Geel's method is simple-each new spore is given a new type number and classification is not affected by what may be artificial morphological differences. I used Clarke's scheme in this thesis because it had been newly developed at Edinburgh and this thesis presented the opportunity to test it in the analysis of fungal spores from a range of different environments.

Clarke's method of recording fungal spores using a set of defined characteristics is, however, an excellent *aide memoire* when describing and

recording fungal microfossils, and I would recommend its use for the recording and description of fungal microfossils in Quaternary palynology.

The study of fossil fungal spores and algal microfossils is hampered by the absence of a published key; information relating to fossil fungal spores in Quaternary studies is largely found in van Geel's papers in the Review of Palaeobotany and Palynology, or in unpublished theses (e.g. Clarke 1994). This makes it very difficult for scholars to study fossil fungal spores, unless they have access to this literature, can visit Dr. van Geel and Dr. Clarke or can collaborate with a mycologist. Given these difficulties, it is hardly surprising that the study of fungal spores and other microfossils remains the province of very few specialists.

A further criticism is that neither of van Geel's, Clarke's or the authors studies have been able to resolve the issue of how one moves from a fossil fungal spore type to the accurate identification of a biological taxon. Presently, this is done through *ad hoc* means of recognizing a fungal spore type in the published fungal literature (van Geel 1978, Clarke 1994). Whilst not a perfect methodology, it has to date led to the identification of over a hundred fossil fungal spores from peats and other deposits.

Finally, we have little understanding of the taphonomy and distribution of fungal spores. At Balnuaran of Clava there was a strong possibility that at least some of the fungal spores recovered were the result of later biological disturbance of the deposits. This possibility of later disturbance leading to replacement of fungal spore communities is likely to be a problem for the study of fungal remains in archaeological deposits. There are, however, several methods that an analyst can use to check if living fungal communities are present in soils; these include the use of stains or radiographic methods to identify living mycelium and viable spores (Søderstrom 1977, Parkinson, Gray and Williams 1970). In this thesis because this was not identified as a potential difficulty, such tests were not performed and the presence of intrusive fungal microfossils was identified through the use of assemblage data.

This thesis involved the use of several different strands of evidence, so it was not possible to complete an in depth study of the fungal spores. From, the above critique it appears that this class of microfossil evidence is a relatively new subject of inquiry in which a great deal of basic research has still to be completed. In general, despite the above serious criti-

cisms I would advocate the palynofacies approach for the study of palaeoenvironments, rather than have separate specialists studying the pollen, fungal, algal etc. components. By incorporating all of these techniques into a single analysis important information about the past can be realized.

Further work.

There are three key areas in which more research is required in order to develop palynofacies analysis in archaeopalynology; microfossil identification, the formation processes of palynofacies assemblages, and the ecological significance of palynofacies assemblages. In all three of these areas the subject is in its infancy.

Further work in palynofacies analysis must be based on the development of secure methods of identification of the various microfossils encountered in routine analysis. Three requirements are needed to provide the same level of taxonomic resolution enjoyed by other disciplines such as palynology. Firstly, the setting up of a group or committee to oversee the taxonomy of microfossils be set up to produce an agreed nomenclature for fungal and *incertae cedis* fossils such as is the case for geological form taxa (Brasier 1980). Such a group or committee could either be set up under the auspices of INQUA, or more informally through one of the institutions currently involved in fungal spore and algal studies e.g. at the Hugo de Vries university. The second would be the production of a series of hierarchical keys to identified fungal spores and algal microfossils along the lines of the European pollen flora. Thirdly, there should be a handbook published detailing the type, ecology and dispersal of non-pollen microfossils encountered within palynological studies.

These three steps would enable the non-pollen microfossils encountered in palynological preparations to be used as a normal part of palynological research. In the absence of keys to non-pollen microfossils it is difficult to see how the use of non-pollen microfossils can develop within either archaeopalynology or palaeoecology.

More work on developing the model of the accumulation of palynofacies assemblages is also required. In particular, the contribution of regional or long distance fungal spore and palynodebris to lake, soil and mire sediments needs to be assessed. Most authors working in the field consider this to be a minor element compared with local production (van Geel 1978, Clarke 1994) but the presence of small amounts of fungal spores in lake

deposits (e.g. Trowie Loch) suggest a regional component certainly exists. Fungal spores are known from aerobiological studies to comprise a large portion of airborne material (Ogden 1974), so that their transport over considerable distances cannot be excluded.

Finally, it should be possible to increase the environmental interpretation of palynofacies assemblages, if more ecological information on the various microfossils encountered can be obtained. The best way to achieve this would probably be through the study of the palynofacies assemblages recovered from modern environments. Such studies could include both the identification of fossil fungi, and algae, but could also use phycological and fungal ecology methods to study the living microfungal and algal communities (Parkinson *et al.* 1971, van den Hoek *et al.* 1995). Such studies should theoretically provide an overall description of the palynofacies assemblages of a range of terrestrial and aquatic environments, for use in palaeoecology. Uses of such techniques could include identification of *in-situ* tree lines, the presence of alder carr on mires, and other situations where a knowledge of local environmental conditions may not be available from other sources e.g. lack of plant macros.

Conclusion

The aim of this study was to examine whether fossil palynofacies assemblages would provide microfossil assemblages capable of providing environmental and archaeological data. This has been proved to be the case. We now know that a palynofacies approach to the analysis of archaeological deposits, buried soils, peats and lake sediments can produce meaningful environmental information over and above that obtained from pollen analysis. The present study therefore confirms and extends the work of van Geel (1978), van Geel *et al.* 1988), Odgaard (1994) and Clarke 1994).

This is an initial study, but the results indicate that two classes of microfossils may be of particular significance for archaeological studies. The first of these are Sordariacious fungal spores, which are indicators of animal dung, burning and cellulose decay and may prove to be of great interest in the study of archaeological sediments (Lundquist 1972, Clarke 1994). The second type are the Cyanophyta in lake sediments which are indicators of increasing eutrophication, which may be correlated with increasingly pollution (van Geel *et al.* 1994). In addition to these extra fossils, a comprehensive analysis of microfossils is one method for better understanding the taphonomy of archaeological deposits and buried soils.

Appendix 1:Preparation Method for pollen samples from peats, soils and lake sediments (after Van Geel pers comm.)

This appendix is divided into two parts the first outlines the overall steps used in the preparation of the samples. The second part tabulates the actual steps used in the preparation of samples from each case study.

Note, soil samples were pre-processed by drying overnight in a oven at 40^{o} Celsius, they were then ground in a mortar and pestle and sieved through a 1mm sieve to remove coarse stony material.

1) 1 cm^3 of sediment is measured by displacement into distilled H_20 in a polypropylene centrifuge tube. Centrifuge at 3000 rpm for five minutes and decant supernatant.

2) (optional) Fill tube with 6 ml 10% HCl for samples likely to contain calcium carbonate, allow to settle after any reaction. Centrifuge at 3000 rpm for five minutes and decant supernatant. Wash with distilled water centrifuge at 3000 rpm for five minutes and decant supernatant, repeat until solution is neutral.

3) (optional) If using exotic add 6 ml 10% HCl then add tablets of *Lycopodium* exotic. Centrifuge at 3000 rpm for five minutes and decant supernatant. Wash with distilled water centrifuge at 3000 rpm for five minutes and decant supernatant, repeat until solution is neutral.

4) Add 6ml 10% KOH place in a boiling water bath for 5-10 minutes stirring occasionally. If solution is in danger of becoming too alkaline due to evaporation top up with distilled water. Centrifuge at 3000 rpm for five minutes and decant supernatant.

5) Wash through a 150 μm sieve into a large centrifuge tube. Centrifuge at 3000 rpm for five minutes and decant supernatant, and return pellet to small centrifuge tube.

6) (optional) If samples contain abundant clay fragments (soils) then after KOH they may be treated with Sodium Pyrophosphate. Ensure samples are neutral then add 0.1M Sodium Pyrophosphate mix and place in a hot water bath for 5-10 minutes. Centrifuge at 3000 rpm for five minutes and decant supernatant.

7) Wash twice with distilled water. Centrifuge at 3000 rpm for five minutes and decant supernatant after each wash.

8) Dehydrate with glacial acetic acid. Centrifuge at 3000 rpm for five minutes and decant supernatant.

9) Add 6 ml acetolysis mixture (nine parts acetic anhydride to one part concentrated sulphuric acid). Heat gently to the boiling point in a hot water bath, between 3-5 minutes. Centrifuge at 3000 rpm for five minutes and decant supernatant.

10) Wash with glacial acetic acid. Centrifuge at 3000 rpm for five minutes and decant supernatant.

11) Wash twice with distilled water. Centrifuge at 3000 rpm for five minutes and decant supernatant after each wash.

12) Wash twice with 96% Alcohol. Centrifuge at 3000 rpm for five minutes and decant supernatant after each wash.

13) Fill the tubes with a Bromoform/alcohol mixture with a specific gravity of 2.0 and centrifuge for 10 minutes at 1500 rpm.

14) Fill other tubes two thirds full with 96% alcohol.

15) After the first tubes have spun a collar of pollen forms at the top of the tube. Carefully decant this collar of pollen into the tubes with the 96% alcohol. Check the remaining residue for pollen and repeat if necessary.

16) Wash with 96% Alcohol. Centrifuge at 3000 rpm for five minutes and decant supernatant.

17) Add 6ml 2 methylpropan-2-ol and one drop of stain (optional but usually safranin) mix well and leave to stand for 1 minute. Centrifuge at 3000 rpm for five minutes and decant supernatant.

18) Wash with 2 methylpropan-2-ol. Centrifuge at 3000 rpm for five minutes and decant supernatant, wash into sample tubes using 2 methylpropan-2-ol. Centrifuge at 2000 rpm for 10 minutes then decant supernatant.

19) Add a small amount of silicone oil (12,500 cs). Centrifuge at 2000 rpm for 10 minutes then place in warm drying cabinet overnight.

Preparation Steps	Meldon Hills	Balnuaran of Clava	Trowie Loch
Step 1	y	y	y
Step 2	n	y	y
Step 3	n	y	y
Step 4	y	y	y
Step 5	y	y	y
Step 6	n	y	n
Step 7	y	y	y
Step 8	y	y	y
Step 9	y	y	y
Step 10	y	y	y
Step 11	y	y	y
Step 12	y	y	y
Step 13	y	y	y
Step 14	y	y	y
Step 15	y	y	y
Step 16	y	y	y
Step 17	y	y	y
Step 18	y	y	y
Step 19	y	y	y

Table A1.1 Table of steps involved in the preparation of samples from the various case studies examined in the thesis. (see above Appendix 1 for detailed description of steps).

Appendix 2: Clarke's 1994 method for the classification of fungal spore types

In this appendix a brief summary of Clarke's system of fungal spore classification is given (1994). For further details, Clarke's thesis should be consulted (1994). A sample blank recording sheet is also illustrated (A2.4).

In this system discrete microfossils are classified on the basis of two characteristic morphological features. These are the numbers of septa and apertures present. Such a system produces twenty form groups (Fig A2.1) to which fungal spores and other discrete microfossils can be assigned. In describing the morphology of fungal spores a number of criteria may be used to deliminate individual spore types within these large groups. Such criteria include:

Aperture details (see fig. A2.2)

Septal details (see Fig. A2.3)

Shape and size

External appendages

Surface ornamentation

Wall structure

Colour

Stain uptake

An additional category was also used in this thesis of IC for *incertae cedis* microfossils. These were defined as microfossils that were clearly not fungal spores and algal cysts and that may have been fern spores or mineral material. Only four such *incertae cedis* microfossils were identified during the study (see Appendix 6 for a detailed description of these types).

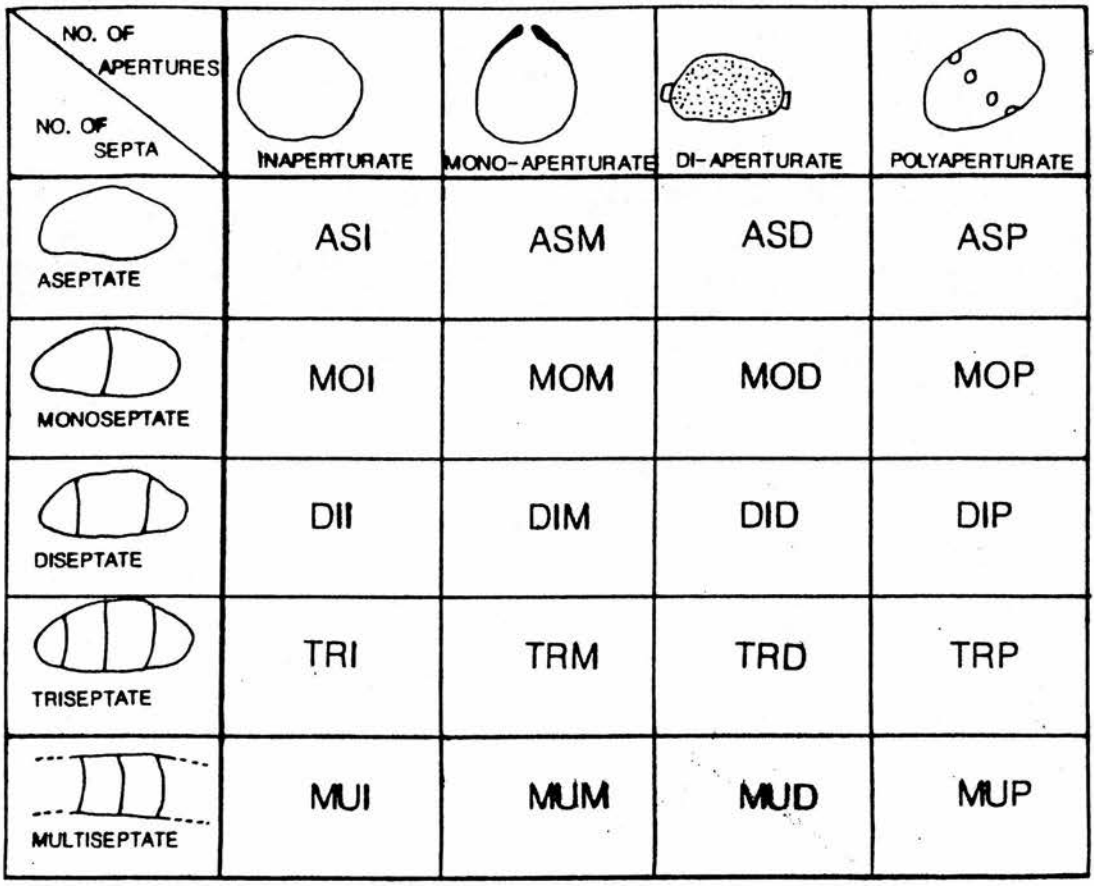


Fig A2.1 Table of form groups for classification of fungal spores and *incertae cedis* microfossils. (after Clarke 1994)

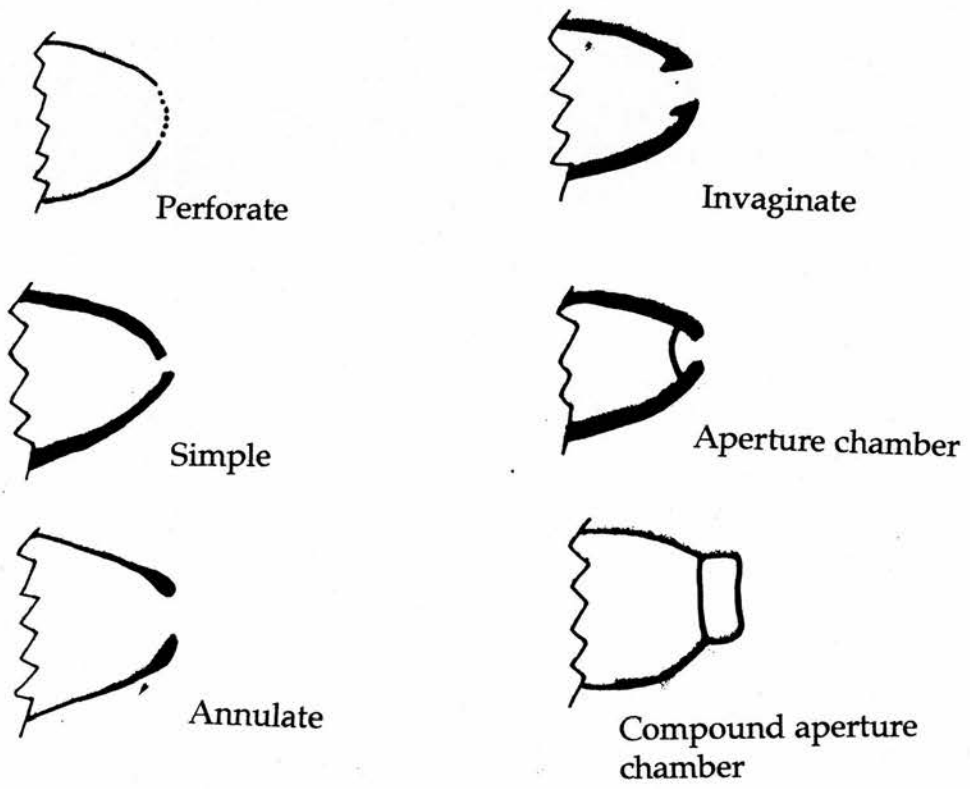


Fig. A2.2 Common fungal spore aperture types (after Clarke 1994)

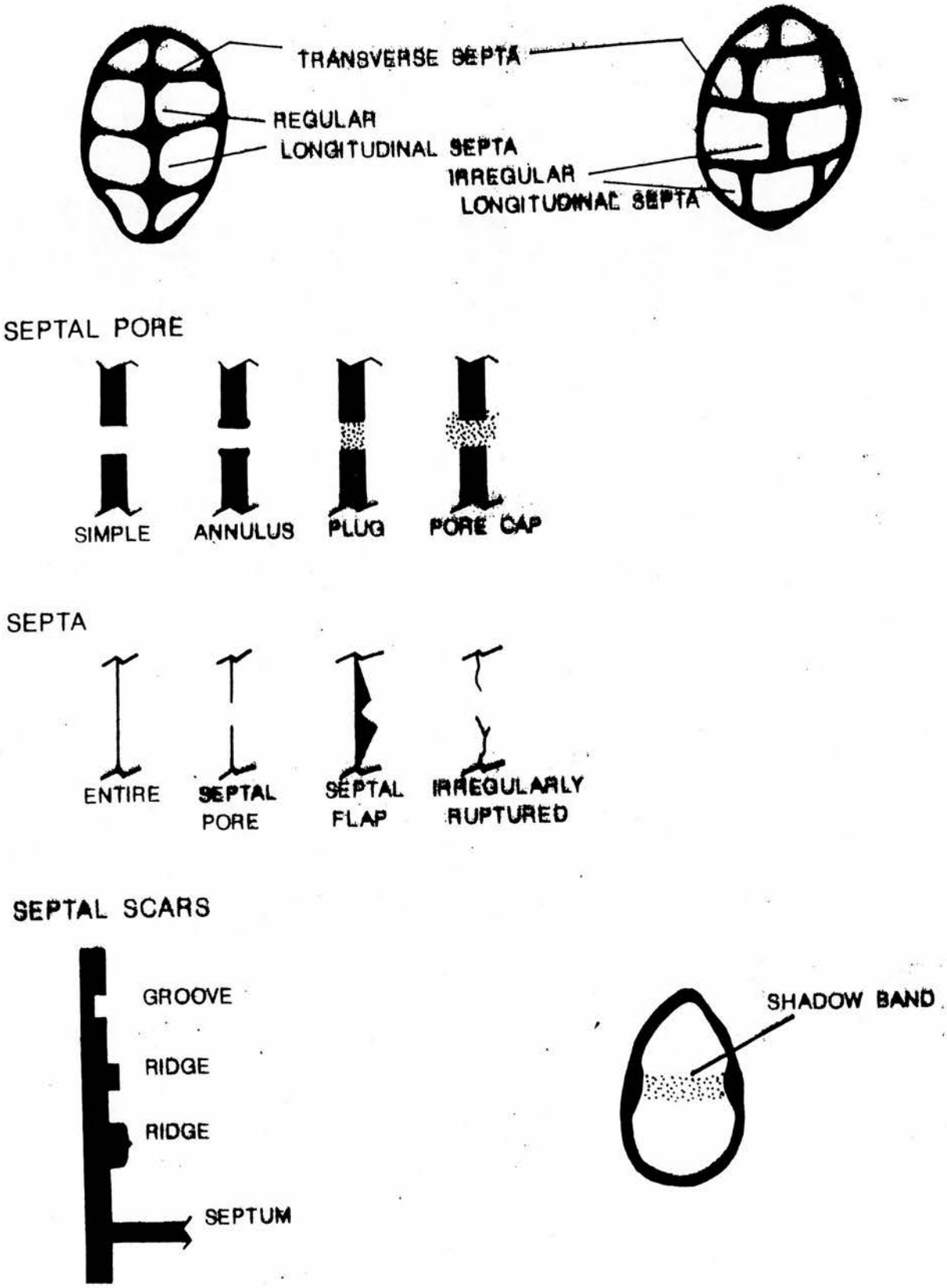


Fig. A2.3 Common fungal spore septal types (after Clarke 1994)

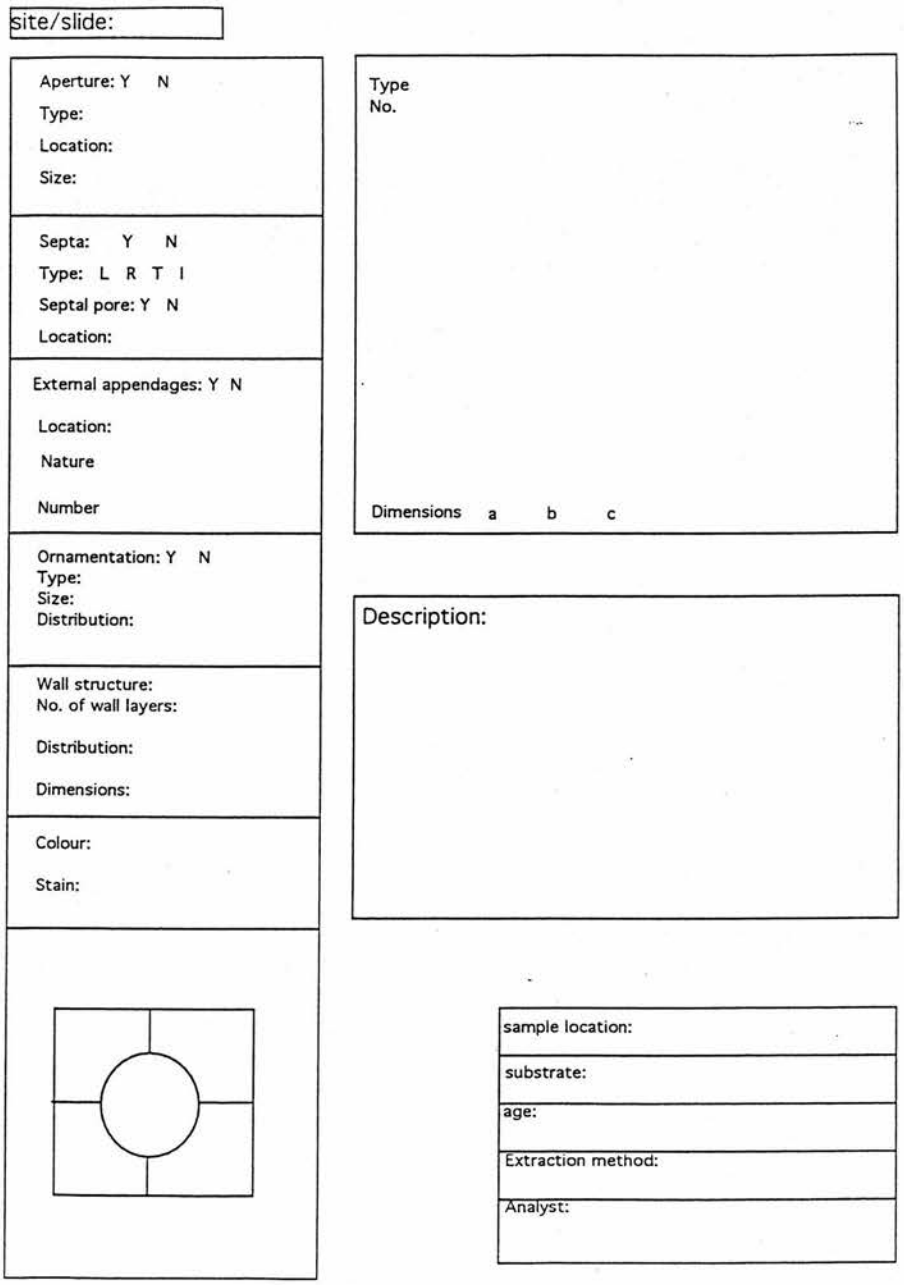


Fig. A2.4 Sample recording sheet for fungal spores and *incertae cedis* microfossils

Appendix 3:Equations for calculating the area of palynodebris on a slide (from Clark 1982)

1) calculate estimated probability of a random point falling on a slide

$P=C/N$

2) Estimate area of charcoal on a slide.

$A=P.Ap$

3) Calculate Standard Deviation of A.

$sA=Ap\ P(1-P)/N$

4)Estimate area of charcoal in a unit volume of sediment using marker grains

$Ac=A.M./MpV$

Key

P=estimated probability of a random point falling on charcoal

C=number of points falling on palynodebris on a slide

N=number of points applied

A=estimated area of charcoal on a slide

Ap=area of sample on slide

sA=standard deviation of A

Ac=estimated area of charcoal in unit volume of sediment

M=number of marker grains added to original sediment sample

Mp=number of marker grains on slide

V= Volume of original sediment sample

Appendix 4: Acid digestion technique for the extraction and concentration of volcanic tephra from peat and lake sediments (from Dugmore and Newton 1996)

1) Contiguous samples approximately 2 cm^3 were removed with a clean spatula from the cores recovered from Trowie Loch.

2)Place the sample in a conical flask (e.g. 150 ml) and break into smaller pieces.

3) Add 50 ml concentrated sulphuric acid (98%).

4) Add a few ml of concentrated nitric acid by pipette.

5) Shake the flask, add Octan-2-ol if reaction becomes to vigorous.

6) Once reaction has subsided add further nitric acid.

7) Repeat steps 4, 5, and 6 until the reaction quickly subsides,

8) Place flask on a hot plate

9) Allow to boil until the liquid turns clear or yellow, it may be necessary to slowly add more nitric acid if the fumes become white before the liquid clears.

10) Once the liquid is clear take off the hot plate and allow to cool.

11) Once cool add distilled water and allow sediment to settle.

12) Carefully decant liquid from the flask, leaving the residue behind.

13) Pour residue into a centrifuge tube and spin at 3000 RPM for five minutes.

14) Decant supernatant.

15) Repeat steps 13 and 14 until pH of the solution is neutral.

16) Store sediment in a small sample bottle.

Appendix 5: Photographs

Figure A5.1

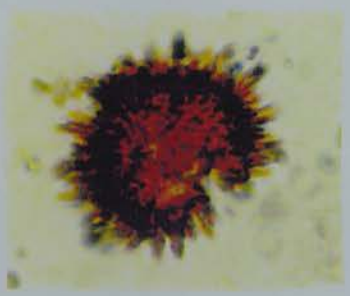


Fig. A5.1.1

Fig. A5.1.2

Fig. A5.1.3

Fig. A5. 1.4

Fig. A5. 1.5

Fig. A5. 1.6

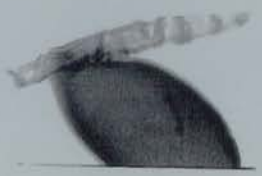


Fig. A5. 1.7

Fig. A5. 1.8

Fig. A5. 1.9

Fig. A5. 1.10

Fig. A5. 1.11

Figure A5.2

Fig. A5. 2.1

Fig. A5. 2.2

Fig. A5. 2.3

Fig. A5. 2.4

Fig. A5. 2.5

Fig. A5. 2.6

Fig. A5. 2.7

Fig. A5. 2.8

Figure A5.3

Fig. A5. 3.1

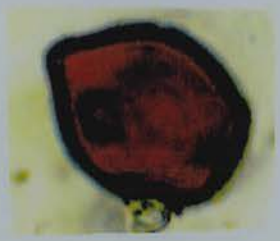


Fig. A5. 3.2

Fig. A5. 3.3

Fig. A5. 3.4

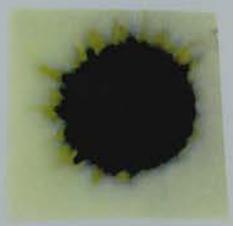


Fig. A5. 3.5

Fig. A5. 3.6

Fig. A5. 3.7

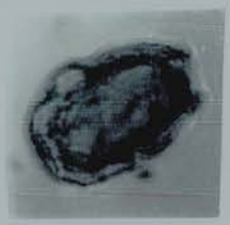


Fig. A5. 3.8

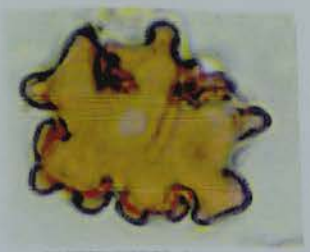


Fig. A5. 3.9

Fig. A5. 3.10

Fig. A5. 3.11

Fig. A5. 3.12

Figure A5.4

Fig. A5. 4.1

Fig. A5. 4.3

Fig. A5. 4.4

Fig. A5. 4.2

Fig. A5. 4.5

Fig. A5. 4.6

Fig. A5. 4.7

Figure A5.5

Fig. A5. 5.1

Fig. A5. 5.2

Fig. A5. 5.3

Fig. A5. 5.4

Fig. A5. 5.5

Fig. A5. 5.6

Fig. A5. 5.7

Fig. A5. 5.8

Fig. A5. 5.9

Fig. A5. 5.10

Fig. A5. 5.11

Fig. A5. 5.12

Fig. A5. 5.13

Fig. A5. 5.14

Figure A5.6

Fig. A5. 6.1

Fig. A5. 6.2

Fig. A5. 6.3

Fig. A5. 6.4

Fig. A5. 6.5

Fig. A5. 6.6

Fig. A5. 6.7

Fig. A5. 6.8

Fig. A5. 6.9

Fig. A5. 6.10

Fig. A5. 6.11

Fig. A5. 6.12

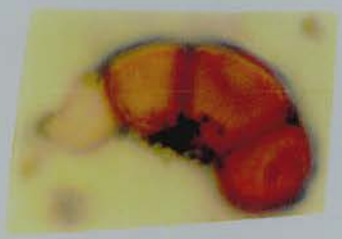


Fig. A5. 6.13

Fig. A5. 6.14

Figure A5.7

Fig. A5. 7.1

Fig. A5. 7.2

Fig. A5. 7.3

Fig. A5. 7.4

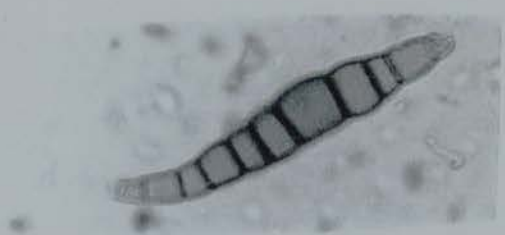


Fig. A5. 7.5

Fig. A5. 7.6

Fig. A5. 7.7

Fig. A5. 7.8

Figure A5.8

Fig. A5. 8.1

Fig. A5. 8.2

Fig. A5. 8.3

Fig. A5. 8.4

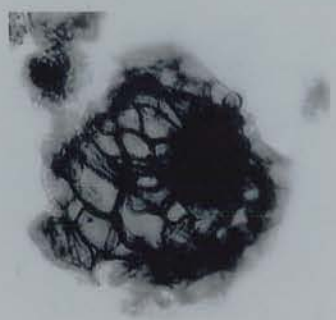


Fig. A5. 8.5

Fig. A5. 8.6

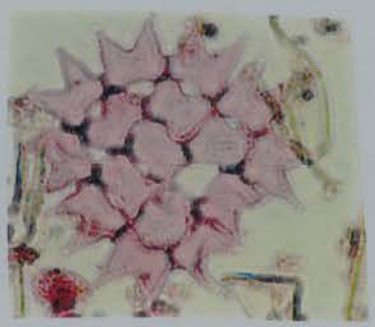


Fig. A5. 8.7

Fig. A5. 8.8

Fig. A5. 8.9

Figure A5.9

Fig. A5. 9.1

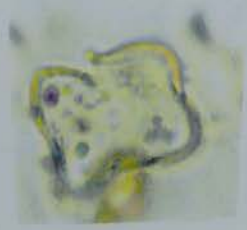


Fig. A5. 9.2

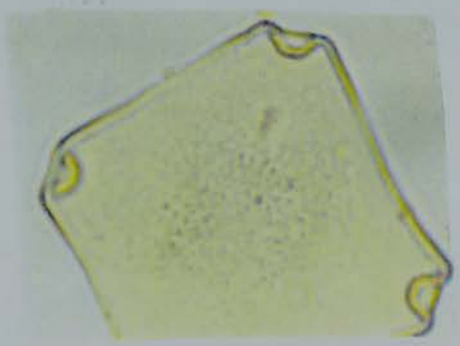


Fig. A5. 9.3

Fig. A5. 9.4

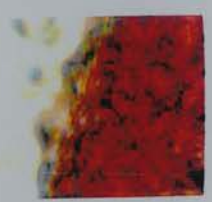


Fig. A5. 9.5

Fig. A5. 9.6

Fig. A5. 9.7

Fig. A5. 9.8

Figure A5.10

Fig. A5. 10.1

Fig. A5. 10.2

Fig. A5. 10.3

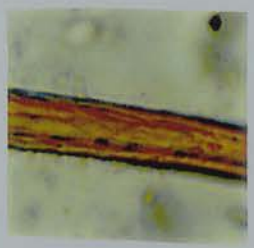


Fig. A5. 10.4

Fig. A5. 10.5

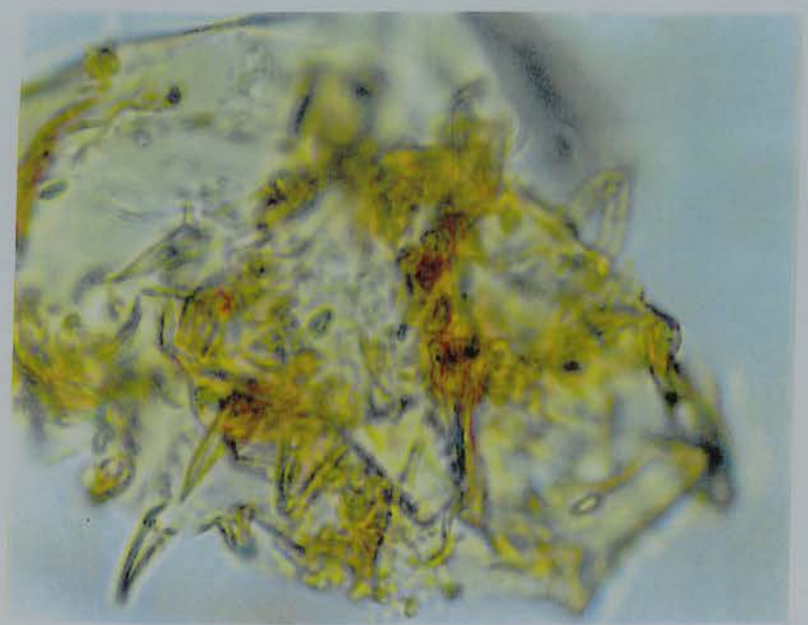


Fig. A5. 10.6

Figure A5.11

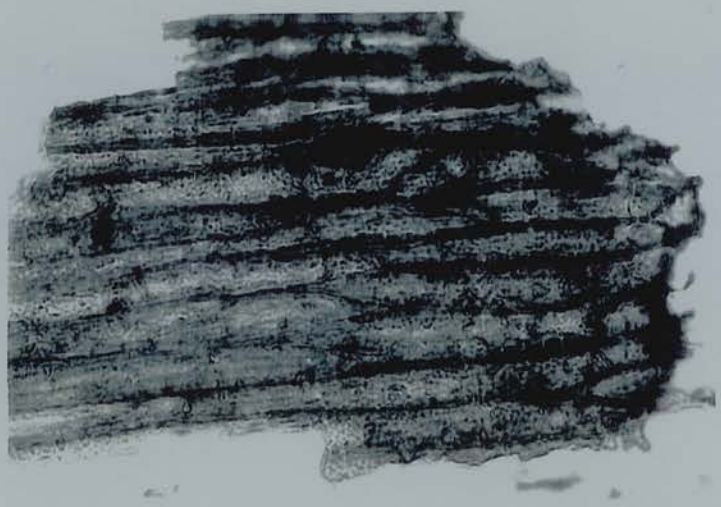


Fig. A5. 11.1

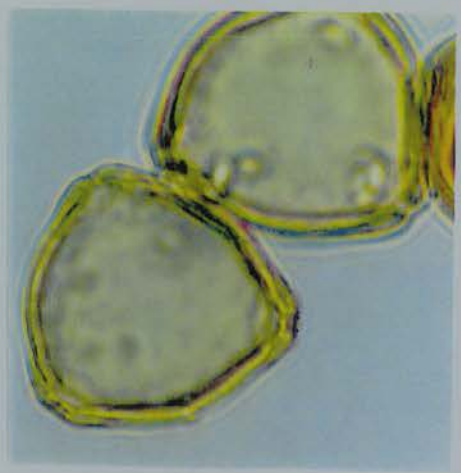


Fig. A5. 11.2

Fig. A5. 11.3

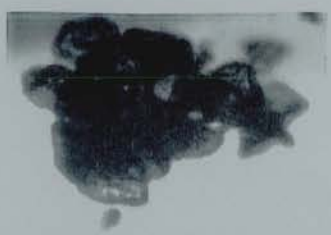


Fig. A5. 11.5

Fig. A5. 11.4

Figure A5.12

Fig. A5. 12.1

Fig. A5. 12.2

Figure A5.13

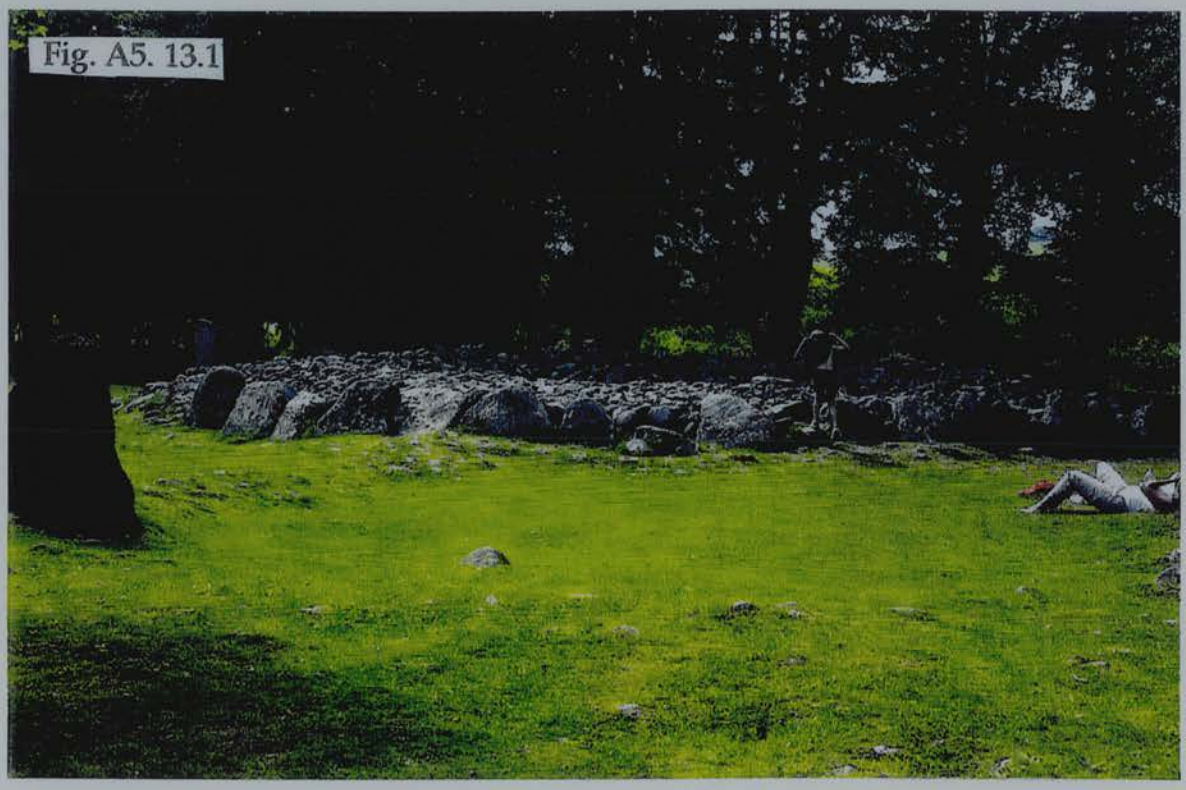


Figure A5.14

Figure A5.15

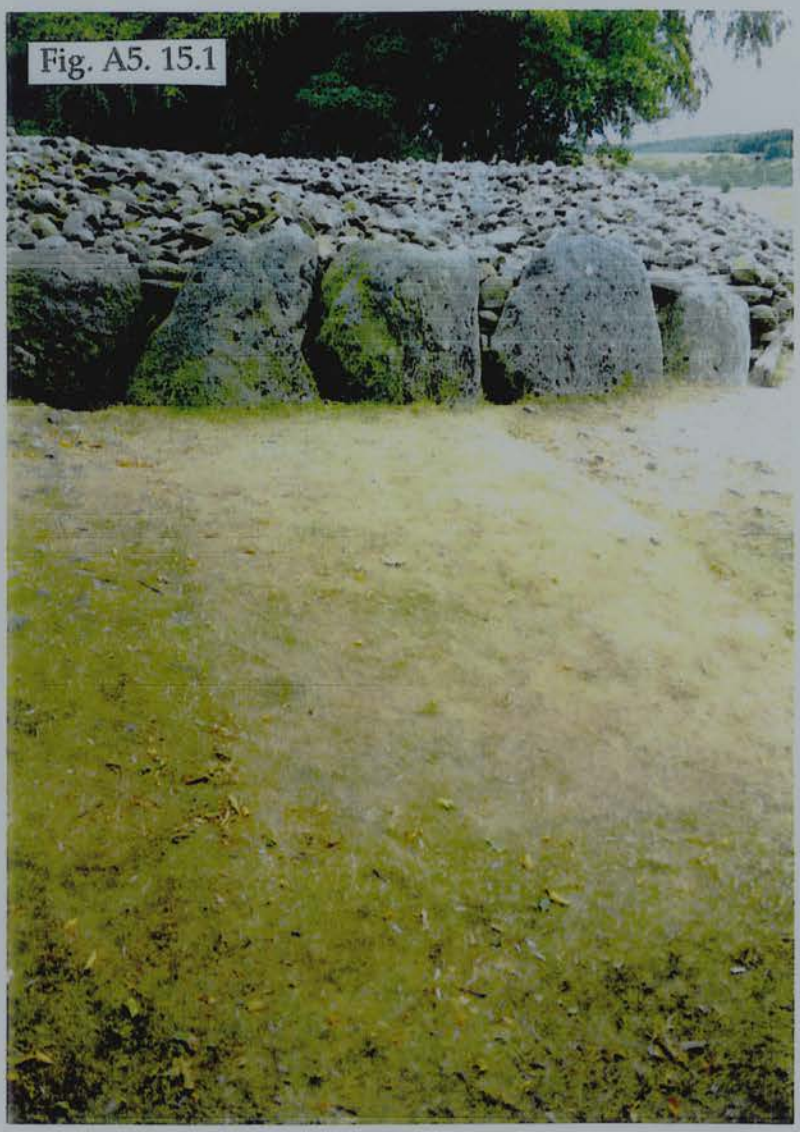


Figure A5.16

Figure A5.17

Figure A5.18

Appendix 6: Catalogue of non-pollen microfossils

In this appendix all of the microfossils identified during the analysis are described. The first section considers the fungal spores, *incertae cedis* and animal microfossils. For each form taxon identified the following information is given; a detailed description, the occurrence of the microfossils in the study, comparative microfossils from other studies and finally a brief discussion of the known ecological information. The second section provides the same information relating to algal microfossils whilst the third section details palynodebris identified in the study.

Section 1: Fungal spores and *incertae cedis* fossils:

ASI003: Globose, aseptate dark. brown- black spores , inaperturate, with a dense covering of echinae ranging in size from 1-3 μm. in length and *c.*1 μm. in diameter. Size range *c.* 16-20 μm in diameter. (Appendix 5: Fig. A5.1.1 (x1000))

Occurrence: Buried soil from Clava cairns

Comparatives: Clarke 1994, ASI012, also Van Geel *et al.* 1983(a) T.181.

Ecology: Not known. Clarke (1994) considers that this type resembles the spores of the Myxomycetes or slime moulds or *Lycoperdon* type. The author examined several species of modern *Lycoperdon* spores but these did not resemble type ASI003.

ASI010: Discoid spore, pale coloured, yellow-pale yellow brown. Appears to have a small 1 μm diam opening on upper surface. Single wall approximately 1μm thick. Size range *c.* 12-14 μm in diameter. Appendix 5: Fig. A5.1.2 (x1000).

Occurrence: Modern samples from Meldon, Buried soils at Clava cairns and mire deposits from Shetland.

Comparatives: Clarke 1994, ASI014, Clarke identified these spores as *Ampelomyces quisqualis*. *Ampelomyces* Ces. ex Schecht.

Ecology: Ellis and Ellis 1988 note that *A. quisqualis* is itself a parasite on other fungi.

ASI017: Obtuse cylindrical inaperturate spore, with smooth surface, single wall >1um thick. Size range 10-15x7-9 μm. Appendix 5: Fig. A5.1.3 (x1000).

Occurrence: Modern samples from Meldon

Comparatives: None

Ecology: Not known

ASI018: Assymetrical/ovoid aseptate, red brown spore with a smooth single wall 1 μm. thick, size range 24-26 x 18-21 μm. Appendix 5: Fig 1.4 (x1000)

Occurrence: Buried soil from Clava cairns and mire deposits from Shetland

Comparatives: None

Ecology: Not known

ASI021: Spherical aseptate spore, hyaline with characteristic surface crinkling. single wall *c.* 1μm thick. size range 20-40 x 20-40 μm. Appendix 5: Fig. A5.1.5 (x1000).

Occurrence: Modern samples from Meldon

Comparatives: None

Ecology: Not known

ASI024: Hemispherical spore with sparse short echinae *c.* 1 μm in length, often underlain by by what appear to be punctae. Single wall 1 μm thick. size range 14x14x6 μm. Appendix 5: Fig. A5.1.6 (x1000).

Occurrence: Buried soil from Clava cairns

Comparatives: None

Ecology: Not known

ASI026: Ellipsoidal spore, inaperturate hyaline, with a single smooth wall >1 μm thick. Size range 10-16 x 5-8 μm.

Occurrence: Buried soil from Clava cairns and mire deposits from Shetland.

Comparatives: None

Ecology: Not known

ASI027: Ellipsoidal aseptate spore with smooth mid brown walls, >1 μm in thickness. size range 18-22 μm x 8-10 μm. Appendix 5: Fig. A5.1.7 (x1000).

Occurrence: Modern samples from Meldon, buried soil from Clava cairns

Comparatives: Clarke 1994, ASI037, a member of the Sordariaceae

Ecology: Sordariaceae are found in association with dung and vegetation (Lundqvist 1972)

ASI029: Lobed aseptate hyaline spore, with a smooth wall, up to 12 lobes emerging from an irregularly subspherical body. Lobes between 2-4μm in height 1-2.5 in width. size range 15-20 x 15-20 μm. Appendix 5: Fig. A5.1.8 (x1000).

Occurrence: Buried soil from Clava cairns

Comparatives: Clarke 1994 ASI078. *cf. Inocybe* (Fr.) Fr. (1863)

Ecology: *Inocybe* are mainly associated with wood or humus, and are often ectomycorrhizal Moser 1978 in Clarke 1994.

ASI030: Discoid dark brown spore with scabrate surface, single wall 1 μm thick. size range 14-16 μm x 2-4 μm . Appendix 5: Fig. A5.1.9 (x1000).

Occurrence: Mire deposits from Shetland

Comparatives: None

Ecology: Not known

ASI035: Globose hyaline microfossil with a single wall *c.*1μm thick. a second outer layer has a thin and wrinkled appearance. size range 28-32 x 28-32 μm. Appendix 5: Fig. A5.1.10 (x1000).

Occurrence: Mire deposits from Shetland

Comparatives: None

Ecology: Not known.

ASI036: Ellipsoidal, pale brown spore with striae *c.* 3 x1 μm in size. single wall 1 μm thick. size range 15-18 x 10-12 μm. Appendix 5: Fig. A5.1.11 (x1000).

Occurrence: Mire deposits from Shetland

Comparatives: None

Ecology: Not known

ASI039: Globose aseptate brown spore with a smooth surface. single wall 1 μm thick. 10-16 μm in diameter. Appendix 5: Fig. A5.2.1 (x1000).

Occurrence: Buried soil from Clava cairns and mire deposits from Shetland

Comparatives: None

Ecology: Not known

ASI040: Reniform, aseptate, inaperturate spores with smooth walls. single wall, 1μm thick. occasionally found in groups of four presumably as part of fruiting body or ascus. size range 17-19x3x4 μm. Appendix 5: Fig. A5.2.2 (x1000).

Occurrence: Buried soil from Clava cairns

Comparatives: Clarke 1994 ASI049

Ecology: Not known

ASI041: Globose, aseptate inaperturate spores with smooth surface. each spore has a suspensor denoting a former attachment to the sporocarp or to other spores. single wall ranging in dimensions from ,1μm to 5μm thick; 20-65 μm in diameter. Appendix 5: Fig. A5.2.3 (x1000).

Occurrence: Buried soil from Clava cairns and mire deposits from Shetland.

Comparatives: Endogenaceae type

Ecology: Generally associated with soils

ASI045: Hexagonal pale yellow plate fragment of a larger organism. Size range *c.* 30-55 x 30-55 μm. Appendix 5: Fig. A5.2.7 (x1000).

Occurrence: Mire deposits from Shetland.

Comparatives: Possibly plates of peridinoid dinoflaggelate cysts see Van Geel *et al.* 1989, T.35.

Ecology: Van Geel *et al.* (1989), has located these microfossils in peats formed under meso-oligotrophic conditions.

ASI046: Bilaterally symmetrical, pale yellow, hyaline animal fragment. *c.* 50-80 x 7-10 μm. Appendix 5: Fig. A5.2.8 (x1000).

Occurrence: Mire deposits from Shetland.

Comparatives: Fragments of Cladocera post abdominal structures see Van Geel 1978, T.72.

Ecology: Species of Cladocera occupy a variety of mire and bog habitats.

ASI047: Ellipsoidal pale brown spore with smooth walls. Single wall *c.* 1 μm thick. Size range 15-18 x 6-8 μm.

Occurrence: Mire deposits from Shetland.

Comparatives: None.

Ecology: Not known.

ASM001: Ovoid brown spore with a smooth surface. single simple pore at pole 1 μm in diameter with a 1 μm thick wall . size range 7-9 x5-7 μm. Appendix 5:Fig. A5.3.1 (x1000).

Occurrence: Buried soil from Clava cairns.

Comparatives: None.

Ecology: Not known.

ASM003: Napiform aseptate brown spore, somewhat irregularly shaped, with a small pore present at the apex, *c.*1 u in diameter, 19x16x10-22x13x15 μm . Appendix 5:Fig. A5.3.2 (x1000).

Occurrence: Modern samples from Meldon, Buried soil from Clava cairns, and mire deposits from Shetland

Comparatives: A member of the Sordariaceae possibly the genus *Tripterospora* Lundqvist (1969) see Van Geel *et al.* (1983a) T.169, Clarke 1994 ASI054

Ecology: Members of the *Tripterospora* (Lundqvist 1969) are associated with dung, and rotting vegetation.

ASM004: Limoniform-ellipsoidal Dark-pale brown coloured spore, with one prominent apical pore.c 1-1.5μm in diam. size range 19x15x15μm -24x17x17μm . Appendix 5: Fig. A5.3.3 (x1000).

Occurrence: Modern samples from Meldon, buried soil from Clava cairns, Mire deposits from Shetland.

Comparatives: See Clarke 1994 ASD001 and Van Geel 1978, T.55 *Chaetomium/Lophitricus* type.

Ecology: Predominately cellulose decomposers. (Hawksworth *et al.* 1995).

ASM005: Napiform aseptate brown spore, somewhat irregularly shaped, with a small pore present at the apex, *c.*1 u in diameter, 19x16x10-22x13x15 μm . Appendix 5: Fig. A5.3.4 (x400).

Occurrence: Buried soil from Clava cairns.

Comparatives: A member of the Sordariaceae possibly the genus *Tripterospora* Lundqvist (1969)) see Van Geel *et al.* T.169, Clarke 1994 ASI054

Ecology: Members of the *Tripterospora* (Lundqvist 1969) are associated with dung, and rotting vegetation.

ASM006: Globose spore with a simple pore 1-2μm in diameter, echinate, echinae 1-3μm in length, 0.5-1μm in diameter, single walled, dark brown. 10-14 μm in diameter. Appendix 5: Fig. A5.3.5 (x1000).

Occurrence: Modern samples from Meldon, buried soils from Clava cairns, mire deposits from Shetland.

Comparatives: see Van Smeerdijk 1989, T.495.

Ecology: Not known, associated with impoverished grassland in modern samples and *Molinia* epidermis in fossil samples.

ASM007: Globose echinate spore with a small pore 1-2 μm in diameter. echinae 0.5-1μm in length. At the pore are two characteristic echinae on either side. Dark brown in colour. 9-14 μm in diameter. Appendix 5: Fig. A5.3.6 (x1000).

Occurrence: Modern samples from Meldon, buried soils from Clava cairns.

Comparatives: see Van Smeerdijk 1989, T.495.

Ecology: Not known, associated with impoverished grassland in modern samples and *Molinia* epidermis in fossil samples.

ASM010: Ellipsoidal spore with single simple pore located to one side of tip and single smooth wall 1μm thick, 23x20x20 μm. Appendix 5: Fig. A5.3.7 (x1000).

Occurrence: Modern samples from Meldon, buried soil from Clava cairns, mire deposits from Shetland.

Comparatives: See Van Geel *et al.* (1983b), T.369. A member of the Sordariaceae, possibly the genus, *Podospora.*

Ecology: *Podospora* spp. are associated with dung (Lundqvist

1972).

ASM012: Oblong microfossil with a simple polar aperture *c.*1-2 μm in diameter, two walled, outer wall has a wrinkled appearance. Size range 17-19 x 11-13 μm. Appendix 5: Fig. A5.3.8 (x1000).

Occurrence: Modern samples from Meldon.

Comparatives: None.

Ecology: Not known.

ASM014: Irregularly shaped pale brown single walled microfossil with a single simple pore cc. 1 μm in diam. has several irregularly shaped projections *c.* 2x3 μm in size. size range 18-24x 18-14 μm.Appendix 5: Fig. A5.3.9 (x1000).

Occurrence: Mire sediments from Shetland.

Comparatives: *Gaeumannomyces* hyphopodia Pals *et al.* 1980, T.126.

Ecology: *Gaeumannomyces* type are associated with Cyperaceae species.

ASM018: Doliform spore with a pore located at one or possibly both poles, may represent individual fragments of a longer septated spore. Single smooth wall. Size range *c.*10-15 μm in diameter. Appendix 5: Fig. A5.3.10 (x1000).

Occurrence: Surface samples from Meldon, buried soil from Clava cairns

Comparatives: None

Ecology: Not known.

ASM020: Spherical pale brown spore with small irregularly spaced echinae scattered thinly across surface. basal annulate pore *c.* 2-3 μm in diam 8-12 μm in diameter. Appendix 5: Fig. A5.3.11 (x1000).

Occurrence: Surface samples from Meldon, Buried soil from Clava cairns.

Comparatives: None.

Ecology: Not known.

ASM025: Animal fragment comprised of pale to mid yellow hexagonal plates (often found separately as ASI045), size range 50-100 x50-75 μm. Appendix 5: Fig. A5.3.12 (x400).

Occurrence: Mire deposits from Shetland.

Comparatives: see Van Geel 1978, T.35.

Ecology: Not known.

ASM027: Small pale brown spore with single simple elongated pore *c.* 8 x 1 μm in size. single simple wall 1 μm thick. size range 12-15 x 5-6 μm.

Occurrence: Mire deposits from Shetland

Comparatives: Van Geel 1978, T.6. Van Geel using the presence of peritheca identified similar microfossils as *Coniochaeta xylarispora* (Ell. & Everh.) Cooke. The absence of peritheca at Trowie Loch, does not allow the specific identification of this type. Coniochaetaceae are members of the Sordariales.

Ecology: Present on dung and rotting wood (Hawksworth *et al.* 1995).

ASM029: Oblong to globose spores with a central colpus *c.* 3-5μm long and 1-2 μm wide. size range 10x5x5-15x7x7 μm . dark -mid brown in colour occasionally two or more may be joined together. Appendix 5: Fig. A5.4.1 (x1000).

Occurrence: Modern samples from Meldon, buried soil from Clava cairns, mire deposits from Shetland.

Comparatives: A member of the Sporormiaceae probably *Sporomiella* spp. See Davis, 1987, Ahmed and Cain 1972.

Ecology: Coprophilous.

ASM030: Large yellow microfossil probably an animal fragment.

size range *c.* 100-150 x 30-70 μm. Appendix 5: Fig. A5.4.2 (x1000).

Occurrence: Mire deposits from Shetland.

Comparatives: None.

Ecology: Not known.

ASM033: Globose hyaline microfossil with large single simple spore *c.* 4 μm in diam. size range 18- 21 x 13-16 μm.

Occurrence: Mire deposits from Shetland.

Comparatives: None.

Ecology: Not known.

ASM035: Ovoid aseptate spore with a single simple pore at tapered end. some examples appear to be thinned in the longitudinally along the long axis. Size range 14-18 x 12-14 μm. Appendix 5: Fig. A5.4.3 (x1000).

Occurrence: Buried soils at Clava cairns, mire deposits from Shetland.

Comparatives: None.

Ecology: Not known.

ASM036: Pyriform spore with a simple apical aperture 2-3 μm in diameter. surface appears pitted perhaps due to corrosion. dark-pink brown in colour. size range 18x10x6-22x11x9 μm. Appendix 5: Fig. A5.4.4 (x1000).

Occurrence: Buried soils at Clava cairns.

Comparatives: None.

Ecology: Not known.

ASM037: Monoporate asymmetrical dark brown fungal spore with a smooth surface pore possibly annulate but is v. small and positioned to one side of the polar tip. size range 30x22x22 μm. Appendix 5: Fig. A5.4.5 (x1000).

Occurrence: Buried soils at Clava cairns and mire deposits from Shetland.

Comparatives: See Clarke 1994, ASI068.

Ecology: Not known.

ASM038: Spherical dark brown spore with a single pore offset to one side *c.* 2 μm in diam. size range 25 x 25 μm. Appendix 5: Fig. A5.4.6 (x 1000).

Occurrence: Buried soil from Clava cairns.

Comparatives: None.

Ecology: Not known.

ASM039: Obtuse slightly ovoid spore, with a annulate pore (1μm in diam), the annulus takes the form of a pronounced collar. pale-mid brown in colour 23x13-27x15 μm. Appendix 5: Fig. A5.4.7 (x1000).

Occurrence: Buried soil at Clava cairns

Comparatives: None

Ecology: Not known

ASM040: A cylindrical spore with a polar pore(1-2 μm diam). surface appears to be mottled with dark patches that may represent low verrucae, but the exact structure is obscured, by the dark colour of the surface. 26x15x15-22x13x13. Appendix 5: Fig. A5.5.1 (x1000).

Occurrence: Buried soil from Clava cairns.

Comparatives: Clarke 1994, ASM011.

Ecology: Not known.

ASM041: Oval spore, with truncated basal pole, other pole has simple aperture 1μm in diam, smooth surface, with one wall. Variably coloured pale pink brown in safranin to hyaline in unstained preparations. 15x5 μm. Appendix 5: Fig. A5.5.2 (x1000).

Occurrence: Buried soil from Clava cairns.

Comparatives: None

Ecology: Not known.

ASM042: Asymmetrical ovoid monoporate spore with a smooth surface. both poles truncated one with a simple pore 1-2 μm in diameter. Brown to black in colour. 23x12 μm. Appendix 5: Fig. A5.5.3 (x1000).

Occurrence: Buried soil at Clava cairns.

Comparatives: None.

Ecology: Not known.

ASM043: Irregular ovoid pale brown spore with a smooth surface has a single germ slit along one side *c.* 1 μm wide. size range 17- 24 x 4-8 μm. Appendix 5: Fig. A5.5.4 (x1000).

Occurrence: Mire deposits from Shetland.

Comparatives: See Van Geel 1978, T.4. Identified as *Anthostomella fuegiana* Speg. on the basis of the presence of fossilised peritheca.

Ecology: Associated with Cyperaceae.

ASP001: Oval, aseptate polyaperturate spore, apertures simple <1μm in diameter, regularly arranged over the spore surface. wall c1 μm thick. 20x11μm. Appendix 5: Fig. A5.5.6 (x1000).

Occurrence: Buried soil from Clava cairns.

Comparatives: Van Geel 1978, T.1. Clarke 1994 ASP001, ASP006, ASP007. A *Gelinapora* spp.

Ecology: Are carbonicolous, and fimicolous and herbicolous

MOI001: Sub bicampanulate pale brown monoseptate spore. simple septate pore *c.* 1 μm in diameter. single wall *c.* 1 μm thick. size range 13-15 x 7-11 μm. Appendix 5: Fig. A5.5.7 (x1000).

Occurrence: Buried soils at Clava cairns, mire deposits from

Shetland.

Comparatives: None.

Ecology: Not known.

MOI002: Ellipsoidal brown monoseptate spore with a simple septal pore *c.* 1 μm in diam. Single wall *c.* 1 μm thick. Size range 18-21 x 9-13 μm. Appendix 5: Fig. A5.5.8 (x1000).

Occurrence: Buried soils at Clava cairns

Comparatives: None.

Ecology: Not known.

MOI004: Ovoid monoseptate pale brown spore. single wall *c.* 1 μm thick. size range 16-19 x 7-9 μm. Appendix 5: Fig. A5.5.9 (x1000).

Occurrence: Surface samples from Meldon.

Comparatives: None

Ecology: Not known.

MOI006: Ovoid, monoseptate spore with smooth surface and hyaline foot chamber. transverse septa with a median simple pore. brown in colour. Size range 16-20x11-15 μm. Appendix 5: Fig. A5.5.10 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

MOI007: Ovoid monoseptate brown spore, with a single smooth wall 1 μm thick. size range 18-22 x8-10 μm.

Occurrence: Modern samples from Meldon and buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

MOI009: Monoseptate, possibly diaperturate didymospore with smooth walls. assymetrical each pole truncated, no pores were observed but clarke observed simple pores *c.*1 μm in diam in similar spores from archaeological material. Median transverse septμm 1μm thick , 50x10 μm. Appendix 5: Fig. A5.5.11 (x400).

Occurrence: Buried soils at Clava cairns and mire deposits from Shetland.

Comparatives: Similar to Clarke 1994, MOD001

Ecology: Not known.

MOI010: Ellipsoidal monoseptate brown spore with *c.* 1 μm wide striae organized in parallel lines along the long axis. Single wall 1 μm thick. size range 18- 25 x 9-13 μm.

Occurrence: Mire deposits from Shetland.

Comparatives: None.

Ecology: Not known.

MOI012: Ovoid assymetrical dark brown monoseptate spore, with a hyaline pedicel that is often broken off. transverse septa with no pore, single smooth wall *c.* 1 μm thick. Size range 18x10x12 μm. Appendix 5: Fig. A5.5.12 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

MOI013: Irregularly ellipsoidal to sub-ellipsoid, monoseptate inaperturate spore with smooth surface. median transverse septa no pore. Usually hyaline normally pale coloured or pink if safranin used. Size range 10-18 x9-7x9-7 μm. Appendix 5: Fig. A5.5.13 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: Clarke 1994, MOI004.

Ecology: Not known.

MOI014: Symmetrical ovoid spore with transverse septa, no pore evident. Hyaline spore body. Size range14 x 8 x 8 μm. Appendix 5: Fig. A5.5.14 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

MOI015: Symmetrical ovoid spore with transverse septa, septal pore median. brown spore cell, with a hyaline basal cell. size range 14x8x8 μm.

Occurrence: Buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

MOI016: Irregularly ellipsoidal, monoseptate, inaperturate spore with transverse median septum, constricted about septum. Very dark spore. Size range 45-52x20-25 μm. Appendix 5: Fig. A5.6.1 (x400).

Occurrence: Buried soils from Clava cairns.

Comparatives: Clarke 1994, MOI014.

Ecology: Not known.

MOI017: Symmetrical ovoid spore with transverse septa, no pore evident. hyaline spore body. single smooth wall 1 μm thick. Size range 15x7x6 μm. Appendix 5: Fig. A5.6.2 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

MOI018: Irregularly ellipsoidal spore, with transverse septum. Septal pore is median and simple 1 μm in diam. Top spore is brown with hyaline attachment. size range 17x12x10 μm. Appendix 5: Fig. A5.6.3 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

MOI019: Fusiform monoseptate spore with smooth surface. Single smooth wall 1 μm thick. size range 15-20x4 μm. Appendix 5: Fig. A5.6.4 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

DII002: Cylindrical diseptate pale brown spore, septal whole with central simple pore. Single smooth wall. Size range 20x7x7 μm. Appendix 5: Fig. A5.6.5 (x1000).

Occurrence: Modern samples from Meldon, buried soils from Clava cairns and mire deposits from Shetland.

Comparatives: None.

Ecology: Not known.

DII003: Ovoid diseptate inaperturate spore with smooth surface. Septa transverse and entire located either side of the mid point. Septal pore is simple. single wall c>1μm thick. size range 22x12x10μm . Appendix 5: Fig. A5.6.6 (x1000).

Occurrence: Modern samples from Meldon, buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

DII004: Oval diseptate spore, septa evenly spaced on either side of the midpoint. Septa have a central simple pore, are transverse and entire. Single smooth wall 1 μm thick. Size range 18-20 x 8-10 μm. Appendix 5: Fig. A5.6.7 (x1000).

Occurrence: Modern samples from Meldon, buried soils from Clava cairns, mire deposits from Shetland.

Comparatives: None.

Ecology: Not known.

DII005: Crescentic fusiform spore diseptate inaperturate spore, with a smooth surface. septa transverse, with a median simple pore. Basal cell frequently hyaline, both end cells have rounded ends, brown. Size range 23x12 μm. Appendix 5: Fig. A5.6.8 (x400).

Occurrence: Buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

DII006: Ovoid diseptate spore with a smooth surface. Septa transverse, with no pore evident. Several examples have a hyaline basal cell. Size range 15-20x10 μm. Appendix 5: Fig. A5.6.9 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

DII007: Elongated ovoid, diseptate, inaperturate spore with a smooth surface. septa transverse, entire, septal pore median, spore slightly constricted at septa. Brown coloured first cell, with a hyaline assymetrical basal attachment. Size range 18-21 x 5-8 μm. Appendix 5: Fig. A5.6.10 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

DII008: Irregularly fusiform diseptate spore with a smooth surface. Septa transverse with a median simple pore. Basal cell is truncated often hyaline and appears to have an attachment scar. Size range 18- 20x6 μm. Appendix 5: Fig. A5.6.11 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

TRI002: Chain like tri-septate spore pale brown. Single wall 1 μm thick. each cell a flattened cylinder *c.* 5x 9 μm. Size range 18-21 x9 μm. Appendix 5: Fig. A5.6.12 (x1000).

Occurrence: Buried soils at Clava cairns.

Comparatives: None.

Ecology: Not known.

TRI003: Irregularly ovoid, triseptate spore with smooth wall. Septa transverse, with no visible pore. Spore is usually crescentic in shape. Single wall 1 μm thick, brown in colour. Size range 20x11 μm. Appendix 5: Fig. A5.6.13 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

TRI005: Crescentic triseptate pale brown spore, each cell a flattened cylinder *c.* 8x 5 μm. Single wall *c.* 1μm thick. Size range 18-24 x 9-11 μm. Appendix 5: Fig. A5.6.14 (x1000).

Occurrence: Modern samples from Meldon.

Comparatives: None.

Ecology: Not known.

TRI006: Oval, triseptate spore with smooth surface, one median and two transverse septa. 52-60x12-15 μm. Appendix 5: Fig. A5.7.1 (x1000).

Occurrence: Modern samples from Meldon.

Comparatives: None

Ecology: Not known.

MUI003: Chain like spore composed of individual smooth walled spores. Spores are pale pink with up to 13 in a chain. Size range 40-58 x 8-9 μm. Appendix 5: Fig. A5.7.2 (x1000).

Occurrence: Mire deposits from Trowie Loch.

Comparatives: None.

Ecology: Not known.

MUI004: Sub-globose spore pale brown in colour. Comprised of several chains of spores connected at the base. Size range 30-70x30-60 μm. Appendix 5: Fig. A5.7.3 (x1000).

Occurrence: Modern samples from Meldon and mire deposits from Trowie Loch.

Comparatives: *Dichtyosporium* spp.

Ecology: Cellulytic decomposers of wood Ellis and Ellis 1988.

MUI006: Fusiform multiseptate brown smooth walled spore. size range 150-250 x 10-12 μm.

Occurrence: Mire deposits from Shetland.

Comparatives: None.

Ecology: Not known.

MUI008: Fragment of circular ? fruit body comprising radiating

septa, which meander and frequently branch. size range 30-45 x 20-50 μm.

Occurrence: Modern samples from Meldon and buried soils from Clava cairns.

Comparatives: Fragment of fruit body similar to Van Geel 1978, T.8.

Ecology: Not known.

MUI010: Spiral shaped multiseptate brown spore. each spore is separated by a transverse septa with a single simple pore *c.* 1 μm in diam. size range 25-30 x 9-10 μm. Appendix 5: Fig. A5.7.4 (x1000).

Occurrence: Mire deposits from Shetland.

Comparatives: Bakker and van Smeerdijk 1982, T.729.

Ecology: Not known.

MUI012: Fusiform multiseptate spore, individual spores vary in size with the third or fourth spore from the pointed apex generally being greater in size. smooth walled brown spore. size range 70-95 x 10-12 μm. Appendix 5: Fig. A5.7.5 (x1000).

Occurrence: Mire deposits from Shetland.

Comparatives: Van Geel *et al.* 1989, T.201

Ecology: Thought by Van Geel to be associated with dry phases of mires.

MUI016: Ellipsoidal multiseptate spore, with transverse, longitudinal and angulo septums. Smooth walled. Size range 25-40 x15 μm. Appendix 5: Fig. A5.7.6 (x1000).

Occurrence: Mire deposits from Shetland.

Comparatives: None.

Ecology: Not known.

ASD002: Ellipsoidal fungal spore with polar simple pores *c.* 1 μm in diameter. Smooth walled. Size range *c.*11-18 x 6-9 μm. Appendix 5: Fig.

A5.7.8 (x1000).

Occurrence Mire deposits from Shetland, surface samples from Meldon Hills.

Comparatives: T.55 van Geel 1978.

Ecology: Possibly a member of the Sordariales, linked with dung, rotting vegetation and burning.

ASD005: Fusiform spore, with two small annulate pores at each pole, smooth surface to the wall which appears to have been thinned in a 2 μm wide longitudinal band. Pale brown/yellow in colour. Size range 18-22x 8-10 x 6 μm. Appendix 5: Fig. A5.7.7 (x1000).

Occurrence: Surface samples from Meldon Hills, buried soils from Clava cairns and mire deposits from Shetland.

Comparatives: Clarke type ASD008 (1994) and T.44 of van Geel (1978).

Ecology. Not known.

IC008: hyaline spores which appear flattened and appear to be monolete. size range 30-40x20-30x6 μm. Appendix 5: Fig. A5.8.1 (x1000).

Occurrence: Buried soils from Clava cairns and mire deposits from Shetland

Comparatives: None.

Ecology: Not known.

IC009: Ellipsoidal hyaline- yellow monolete spore, with simple walls no evidence of columellae. size range 20-30x 10-14 μm. Appendix 5: Fig 8.2 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: None.

Ecology: Not known.

IC010: a neat rhombic shaped crystal of a translucent brown

colour it is either a very exotic fungal spore or is mineral in origin. Size range 30 x 30 μm. Appendix 5: Fig. A5.8.3 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: None, probably a mineral grain, possibly pyrites.

Ecology: Not known.

IC011: spherical aseptate spore, with 1μm wide anastomosing striae, over surface. these appear to be projections from a single wall. 30 μm in diameter. Appendix 5: Fig 8.4 (x1000).

Occurrence: Buried soils from Clava cairns.

Comparatives: A member of the Endogenaceae. *cf.* van Geel *et al.* 1989, T.207 and Clarke (1994) ASI020.

Ecology: Not known.

Agglomerate: large groups of spores organized into a regular or semi-regular pattern. Appendix 5: Fig 8.5 (x400).

Occurrence: Modern samples from Meldon, buried soils from Clava cairns and mire deposits from Shetland.

Comparatives: None.

Ecology: Not known.

Phomoid: large groups of spores associated in an irregular organization. Appendix 5: Fig 8.6 (x400).

Occurrence: Modern samples from Meldon, buried soils from Clava cairns and mire deposits from Shetland.

Comparatives: None.

Ecology: Not known.

Toruloid fragment: Long single rows of cells, which are somewhat intermediate between hyphal fragments and spores.

Occurrence: Modern samples from Meldon, buried soils from Clava cairns and mire deposits from Shetland.

Comparatives: None.

Ecology: Not known.

Section 2: Algal and Cyanophyta microfossils

ASI037: Tetrahedral spore hyaline with four projections. single wall 1μm thick. size range 17-19 x 15-17 μm.

Occurrence: Mire deposits from Shetland

Comparatives: Algal spore probably related to Van Geel T. 66 1978.

Ecology: Not known

ASI042: Globose to ellipsoidal hyaline microfossil with numerous echinae *c.* 1-5-2 μm in length. single wall 1 μm thick. size range 34-36x 24-26 μm. Appendix 5: Fig. A5.2.4 (x1000).

Occurrence: Mire deposits from Shetland.

Comparatives: None, probably an algal microfossil

Ecology: Not known

ASI043: Globose hyaline smooth walled microfossil with a single wall *c.* 1μm thick. size range 15-20 μm in diameter. Appendix 5: Fig. A5.2.5 (x1000).

Occurrence: Mire deposits from Shetland.

Comparatives: None, probably an algal microfossil.

Ecology: Not known.

ASI044: Bilaterally symmetrical sub-rectangular hyaline microfossil with a single wall 1 μm thick. size range 10-18 μm x 10-18 μm. Appendix 5: Fig. A5.2.6 (x1000).

Occurrence: Mire deposits from Shetland.

Comparatives: Semi cells of the Desmidiaceae, see Van Geel *et al.* 1989, T.332C

Ecology: Pioneer algae (Van Geel *et al.* 1989).

ASI048: Quadrilateral hyaline microfossil with smooth surface. Each point of the quadrilateral contains a small pit. 1-3 μm in diameter. size range 22-28x 25-30 μm. see *Mougeotia*

Occurrence: Mire deposits from Shetland

Comparatives: A species of *Mougeotia* see Van Geel *et al.* 1989, T.313F.

Ecology: Not known

ASM045: Globose microfossil hyaline with a covering of thin short spines less than 1 μm in length. size range 18-24 μm in diam. Appendix 5: Fig. A5.5.5 (x1000).

Occurrence: Mire deposits from Shetland.

Comparatives: See Van Geel *et al.* 1989, T.128. a type of algal cyst.

Ecology: Associated with fresh water.

Gleotrichia type: Tubular hyaline sheaths, sometimes grouped into colonies. SIze range 20-80x 7-9 μm. Appendix 5: Fig. A5.8.8 (x400).

Occurrence: Lake and mire deposits from Shetland.

Comparatives: Type 146 (van Geel *et al.* 1983a, 1988).

Ecology: Nutrient poor or nitrogen poor open water (van Geel *et al.* 1988).

Pediastrum type: Colonial algae formed from small *c.* 4-6 μm. hyaline cells which form symmetrical aggregations. Size range *c.* 40- 100 μm diameter. Appendix 5: Fig. A5.8.7 (x400).

Occurrence: lake and mire sediments from Shetland.

Comparatives: *Pediastrum* spp.

Ecology: able to withstand a variety of water conditions.

Botryococcus type: Symmetrical largely circular colonial algae brown in colour. Size range 10-30 μm in diameter. Appendix 5: Fig. A5.8.9 (x400).

Occurrence: lake and mire sediments from Shetland.

Comparatives: *Botryococcus* spp.

Ecology: able to withstand a variety of water conditions.

Spirogyra type: hyaline bilaterally symmetrical spores with what appears to be a single fold or colpus. Size range *c.* 40-80x20 μm. Appendix 5: Fig. A5.9.1.

Occurrence: lake and mire sediments from Shetland.

Comparatives: *Spirogyra* spp (van Geel 1978, van Geel *et al.* 1988)

Ecology: open shallow probably temporary pools.

Tetrahedron c. T.minimum type: small hyaline symmetrical spores. Size range 8-15 μm. Appendix 7. Fig. A5.9.1.

Occurrence: Lake sediments from Shetland.

Comparatives: *Tetrahedron* spp.

Ecology: eu-mesotrophic open water (Bakker & van Smeerdijk 1982).

Mougeotia type: Square or quadrilateral hyaline microfossils, with small *c.*1 μm diameter pores at the corners. Size range *c.* 20-30 μm in size.

Occurrence: Lake sediments from Shetland.

Comparatives *Mougeti a* spp.

Ecology: eu-mesotrophic water (van Geel 1978).

Zygnemataceae type: Ellipsoidal hyaline spores, with many small dents *c.* 1μm in diameter. Size range *c.* 20-40 x20-25 μm.

Occurrence: Lake sediments from Shetland.

Comparatives: Zygnamataceae spp.

Ecology: Stagnant, shallow, mesotrophic fresh water (van Geel 1978).

Section 3: Palynodebris

Amorphous organic matter: Dark-yellow brown irregularly shaped translucent matter with no clear organization i.e. cell structure etc. Size range *c.*5-100 μm in diameter. Appendix 5: Fig. A5.9.5 (x400).

Occurrence: Surface soil samples from Meldon Hills, buried soils from Balnuaran of Clava and lake and mire sediments from Shetland.

Comparatives: n/a

Ecology: May indicate preservation state of deposits, tends to correlate with wetter periods of mire formation at Trowie Loch.

Brown carbonized material: Mid to dark brown plant debris, irregularly shaped fragments. Internally, a great degree of cell structure is preserved. Size range *c.* 40-100 μm average diameter of fragments. Appendix 5: Figs. 9.6 & 9.7.

Occurrence: Buried soils from Balnuaran of Clava.

Comparatives: n/a

Ecology: At Balnuaran of Clava may represent preserved coniferous material but this is not confirmed.

Charcoal: Black, carbonized material, often irregularly shaped with occasional conchoidal fracture. Seldom shows any degree of internal organization, but occasional cell outlines may be seen. Size range *c.* 5-100 μm in diameter. Appendix 7, Fig 9.8.

Unpigmented (clear) hyphae: long sheath like filaments of hyaline strands. Occasionally sub divided by septa. Size range 20-200 x 4-6 μm. Appendix 5: Fig. A5.10.1.

Occurrence: Buried soils at Balnuaran of Clava.

Comparatives n/a.

Ecology: Interpreted as indicating growth of recent fungal communities due to disturbance of buried archaeological deposits.

Pigmented (brown) hyphae. long sheath like filaments of brown coloured strands. Occasionally, sub divided by septa and attached to conidial spores. Size range 20-200x4-9 μm. Appendix 5: Fig 10.2.

Occurrence: Soil samples from Meldon Hills, buried soils at Balnuaran of Clava, lake and mire deposits from Shetland.

Comparatives: fungal spp.

Ecology: Interpreted by Andersen (1979) and Aaby (1984) as indicating type of soil fauna present in a buried soil. By Cushing (1964) as indicating soil erosion in lake sediments, and by Middeldorp (1982) as indicating wet/dry phases in mire sediments and overall biological productivity of mires.

Gel: Orange-brown irregularly shaped matter, often with an arcuate or conchoidal fracture. Size range 10-30 μm in diameter. Appendix 5: Fig. A5.10.3.

Occurrence: Lake sediments from Shetland

Comparatives: n/a.

Ecology: not known.

Hair: filaments often tapering to a point range of colours from hyaline to orange brown. Size range 10-40x3-6 μm. Appendix 5: Fig. A5.10.4.&10.5.

Occurrence: Soil samples from Meldon Hills, buried soils at Balnuaran of Clava, lake and mire deposits from Shetland.

Comparatives: a variety of plant root hairs may be suggested for this class of palynodebris.

Ecology: not known.

Insect Fragments: Hyaline irregularly shaped often crumpled mat-

ter, contains identifiable parts of insect remains e.g. limb fragments, mouth pieces etc. Size range 20-100x 20-40 μm. Appendix 5: Fig. A5.10.6.

Occurrence: Soil samples from Meldon Hills, buried soils at Balnuaran of Clava, lake and mire deposits from Shetland.

Comparatives: n/a.

Ecology: As a class insect fragments have no clear ecological signal but if individual types can be identified e.g. Chironomids (van Geel 1978) then useful palaeoecological information can be obtained.

Plant cells: irregularly shaped yellow- light brown fragments with clear internal cell division. Size range 20-100x 20-100 μm.

Occurrence: Soil samples from Meldon Hills, buried soils at Balnuaran of Clava, lake and mire deposits from Shetland.

Comparatives: n/a.

Ecology: It is seldom possible to identify plant material in pollen preparations to species. In this study there was no indication that types of plant material were present in sufficient quantity to make the study of plant cells to species worthwhile.

Appendix 7:
Table of named fungal spore taxa derived from Clarke 1994 and various papers of the Hugo de Vries institute.

This appendix brings together those fungal spore microfossils identified to a particular species, genus or family of the fungi by either van Geel and his colleagues or by Clarke (1994). The aim of this appendix is to demonstrate the relatively large number of known fungal taxa and their indicator value. It can be difficult when working purely from the mass of publications of form taxa (e.g. van Geel 1978 or Clarke 1994), to appreciate the taxonomic affinities of the form taxa and where they fit into the overall classification of the fungi. By bringing together the identifiable fungal spore types it is hoped to stimulate the search for more identifiable fungal spore types.

In terms of the biology of recovered fungal spore fossils what Appendix 7 does show is that most identifiable fossil fungal spores principally derive from the Ascomycota, which in turn are dominated by representatives of the Sordariaceae. This bias may represent differences in spore preservation and recovery between the various fungal spore phyla, or more probably is the result of the limited number of environments examined for fossil fungal spore content. To date peat and lake sediments and a variety of human influenced environments have been studied for their fungal spore content. This appears to have heavily influenced the types of fungal spore so far identified. For example the large number of different types of Sordariaceae fungal spores identified by Clarke (1994) reflects the agricultural focus of her modern day sampling strategy, involving as it did farm buildings, pasture fields and muck heaps. Nomenclature and taxonomy follows Hawksworth *et al.* (1995).

Type No.	Phylum:Order:	Family	Taxon Name.	Indicator Value	Reference.
	Ascomycota: Dothideales				
		Herpotrichiellaceae			
22			Herpotrichiella spp.	wood?	van Geel 1978
		Lophiostomataceae			
89			Tetraploa aristata	many host plants	van Geel 1978
MUI008			Tetraploa aristata	herbicolous	Clarke 1994
		Microthyriaceae			
8A			Microthyriaceae	n/a	van Geel 1978
8B			Microthyrium spp.	saprophytic on plant remains	van Geel 1978
8F			Actinopeltis spp.	n/a	van Geel 1978
ASM016			Microthyriaceae	saprophytes	Clarke 1994
ASM018			Microthyriaceae	saprophytes	Clarke 1994
ASM019			Microthyriaceae	saprophytes	Clarke 1994
ASM045			Microthyriaceae	saprophytes	Clarke 1994

ASM048		Microthyriaceae	saprophytes	Clarke 1994
	Mycosphaerellaceae			
67		Cladosporium spp.	n/a	van Geel 1978
ASI035		Cladosporium	cellulose decomposer	Clarke 1994
MOI001		Cladosporium	saprophytic	Clarke 1994
TRI007		Cladosporium	saprophytic	Clarke 1994
	Pleosporaceae			
3B		Pleospora spp.	n/a	van Geel 1978
MUI006		Alternaria	herbicolous	Clarke 1994
MUI020		Alternaria	herbicolous	Clarke 1994
MUI011		Pleospora	herbicolous	Clarke 1994
	Sporomiaceae			
ASI042		Sporomia	fimicolous/ lignicolous	Clarke 1994
MOI008		Delitschia	coprophilous	Clarke 1994
MOD002		Delitschia	coprophilous	Clarke 1994
	Ascomycota: Leotiales			
	Geoglossaceae			
77A		Geoglossum sphagnophilum	sphagnum	van Geel 1978, van der Wiel 1982
77B		Trichoglossum cf. hirsutum	sphagnum	van Geel 1978, van der Wiel 1982
	Ascomycota: Meliolales			
	Meliolaceae			
14		Meliola cf. niessleana	Calluna vulgaris/ dry conditions	van Geel 1978, Kuhry 1985
TRI012		Meliola niessleana	Calluna vulgaris/ dry conditions	Clarke 1994
	Ascomycota: Onygenales			
	Onygenaceae			
ASI002		Histoplasma capsulatum	soil/ bird dung	Clarke 1994
	Ascomycota:Sordariales			
	Ceratostomataceae			
ASD004		Sphaerodes	coprophilous	Clarke 1994
ASD020		Sphaerodes	coprophilous	Clarke 1994
	Chaetomiaceae			
7A		Chaetomium spp.	cellulose decomposers	van Geel 1978, 1988, Kuhry 1985
ASD001		Chaetomium/ Lophitricus	cellulose decomposers	Clarke 1994
ASD023		Chaetomium/ Lophitricus	cellulose decomposers	Clarke 1994
	Coniochaetaceae			
6		Coniochaeta xylarispora	decaying wood/soil	van Geel 1978, Kuhry 1985
172		Coniochaeta cf. ligniara	dung/ wood	van Geel 1983
	Lasiosphaeriaceae			
63A		Lasiosphaeria cf. caudata	lignicolous	van Geel 1978
63B		Lasiosphaeria spp.	n/a	van Geel 1978
63C		Lasiosphaeria spp.	n/a	van Geel 1978
169		cf. Tripterospora	coprophilous/ lignicolous	van Geel et.al. 1983
466		cf. Podospora sp.	coprophilous	Kuhry 1985
730		c.f. Zopfia sp.	soil fungi	Bakker 1982
ASI048		Apiosordaria verruculosa	n/a	Clarke 1994
TRI010		Chaetosphaerella	fungal parasite	Clarke 1994
	Sordariaceae			
1		Gelinaspora spp.	Carbonicolous, lignicolous, fimicolous	van Geel 1978,1988, Kuhry 1985
2		G. reticulispora	local dryness	van Geel 1978,1988
ASP001		Gelinaspora type	fimicolous/ herbicolous	Clarke 1994

ASP006	Gelinaspora type	fimicolous/herbicolous	Clarke 1994
ASP007	Gelinaspora type	fimicolous/herbicolous	Clarke 1994
55A	Sordaria spp.	mesotrophic conditions	van Geel 1978, 1983, Bakker 1982,
55C	Neurospora spp.	charred vegetable matter	van Geel 1978
112A, B, C	Cercophora spp.	coprophilous, lignicolous	van Geel 1978, 1983, van der Wiel
1982, Bakker 1982			
528	Gelasinospora		
	c.f calopora	coprophilous	van Geel 1983
ASI037	Sordariaceae	fimicolous/ herbicolous	Clarke 1994
ASI039	Sordariaceae	fimicolous/ herbicolous	Clarke 1994
ASI052	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASI053	Sordariaceae		
	cf. Tripterospora	fimicolous/herbicolous	Clarke 1994
ASI070	Sordariaceae		
	cf. Tripterospora	fimicolous/herbicolous	Clarke 1994
ASI072	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASI079	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM008	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM012	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM013	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM015	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM021	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM024	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM025	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM026	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM029	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM031	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM041	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM044	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM050	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASM051	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASD002	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASD005	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASD006	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASD007	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASD016	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASD017	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASD024	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASD026	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASD030	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASD031	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASD035	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASP010	Sordariaceae	fimicolous/herbicolous	Clarke 1994
ASD027	Neurospora	carbonicolous	Clarke 1994
Ascomycota: Trichosphaeriales			
Trichosphaeraceae			
ASM001	Nigrospora	herbicolous	Clarke 1994
Ascomycota: Xylariales			
Xylariaceae			
4	Anthostomella		
	fuegiana	Cyperaceae sp.	van Geel 1978, Kuhry 1985
44	Xylariaceae?	n/a	van Geel 1978, van der Wiel 1982
93	Xylariaceae	n/a	van Geel 1978
ASD012	Xylaria	lignicolous	Clarke 1994
ASD013	Xylaria	lignicolous	Clarke 1994
Ascomycota: Incertae sedis			
MUI007	Bactrodesmium	lignicolous	Clarke 1994
Magnaporthaceae			
25	cf. Clasterosporium		
	caricinum	sedges?	van Geel 1978
126	Gaeumannocyces cf.		

	caricis	Cyperaceae spp.	Pals 1980, van Geel 1983, 1988
	Diporothecaceae		
143	Diporotheca spp.	n/a	van der Wiel 1982, van Geel 1986, 1988
	Hyponectriaceae		
105	c.f. Physalospora spec.	n/a	van Geel 1978
	Basidiomycota: Agaricales		
	Bolbitiaceae		
ASM002	Bolbitiaceae and Coprinaceae	saprophytes and coprophiles	Clarke 1994
ASM009	Bolbitiaceae and Coprinaceae	saprophytes and coprophiles	Clarke 1994
ASM047	Bolbitiaceae and Coprinaceae	saprophytes and coprophiles	Clarke 1994
	Basidiomycetes: Cortinariales		
	Cortinariaceae		
ASI077	Inocybe spp.	humus or wood	Clarke 1994
ASI078	Inocybe spp.	humus or wood	Clarke 1994
	Basidiomycetes: Lycoperdales		
	Lycoperdaceae		
ASI012	Lycoperdon type/ Myxomycetes	soil/ pasture/ woodland	Clarke 1994
	Basidiomycota: Ustilaginales		
	Tilletiaceae		
27	Tilletia sphagni	sphagnum	van Geel 1978, Kuhry 1985, van der Wiel 1982
	Ustilaginaceae		
117	Ustulina deusta	lignicolous	Pals 1980
ASD038	Ustulina deusta	lignicolous	Clarke 1994
	Basidiomycota:Uridinales		
ASM054	Ureda spp.	plant parasite	Clarke 1994
	Pucciniaceae		
529	Puccinia cf. magnusiana	saprophytic	van Geel 1983
	Melamsporaceae		
ASI060	Melamspora spp.	plant parasites	Clarke 1994
	Chytridiomycota: Chytridiales		
	Endochytricaceae		
13	c.f. Entophylictis lobata	aquatic/saprophytic	van Geel 1978, Kuhry 1985
	Zygomycota:Endogonales		
	Endogonaceae		
207	Glomus cf. fasciculatum	soil fungi	van Geel 1988, 1983
ASI020	Endogenaceae	soilborne fungi	Clarke 1994
	Mitosporic fungi (Deuteromycetes)		
30	Helicoon pluriseptatum	n/a	van Geel 1978, Kuhry 1985
51	Sporidesmium spp.	n/a	van Geel 1978
95	cf. Stemphyliomma valparadisiacum	n/a	van Geel 1978
96A	Beltrania type	n/a	van Geel 1978
98	cf. Spadicoides bina	lignicolous	van Geel 1978
462	cf.Brachysporium sp. phragmoconidia	n/a	Kuhry 1985
465	cf. Trichocladium opacum	n/a	Kuhry 1985
ASI014	Ampelomyces quisqualis	fungal parasite	Clarke 1994
MUI016	Ampelomyces quisqualis	fungal parasite	Clarke 1994
MUP001	Asterosporium	lignicolous	Clarke 1994

MOI006	Brachyosporium	lignicolous	Clarke 1994
MOM002	Brachyosporium	lignicolous	Clarke 1994
DII003	Brachyosporium	lignicolous	Clarke 1994
DII004	Brachyosporium	lignicolous	Clarke 1994
DIM001	Brachyosporium	lignicolous	Clarke 1994
DIM003	Brachyosporium	lignicolous	Clarke 1994
TRD001	Brachyosporium	lignicolous	Clarke 1994
MUI001	Helminthosporium	herbicolous	Clarke 1994
TRI014	Spadicoides	lignicolous	Clarke 1994
MUI002	Stagonospora	associated with Carex and Phragmites spp.	Clarke 1994

Appendix 8: Method for preparing burnt pollen grains

Hazel pollen was collected in early spring, and after mixing with powdered lime placed in a oven where it was heated at 300 ^{o} Celsius for 15 minutes. The lime was then dissolved and after acetolysis the pollen mounted in Silicone oil. A normal Hazel pollen grain is pictured in Fig A5. 11.2 and a burnt Hazel pollen grain in Fig A5. 11.3. Recovered burnt fossil hazel grains from Location A are pictured in Figs. A5. 11.4-5.

Appendix 9: Table of Radiocarbon dates from Balnuaran of Clava

Balnuaran of Clava South west passage grave

Lab No.	Location	Material dated	Uncal BP	cal BC(1σ)
AA-21251	Chamber	Hazel (1 piece)	2740±55	972-830
AA-21252	Chamber	Hazel (1 piece)	2770±55	986-845
AA-21253	Chamber	Hazel (1 piece)	2790±60	1009-896
AA-21254	Chamber	Hazel (1 piece)	2765±60	996-840
AA-21261	Chamber	Hazel (1 piece)	2855±70	1151-923

Balnuaran of Clava Central ring cairn

Lab No.	Location	Material dated	Uncal BP	cal BC(1σ)
AA-21255	Cairn core	Hazel (1 piece)	6410±80	5474-5242
AA-21256	Cairn core	Hazel (1 piece)	3605±75	2124-1885
AA-21257	Cairn core	Birch (1 piece)	2990±70	1383-1107
AA-21258	located between cairn and the outer stone circle	Birch (1 piece)	1445±130	440-680
AA-21259	located between cairn and the outer stone circle	Hazel (1 piece)	1290±95	653-856
AA-21260	From one of the sockets of the outer stone circle	Scots pine(1 piece)	6670±85	5638-5486

Balnuaran of Clava North east passage grave

AA-25237 o	From the socket fa kerbstone by the entrance passage of the NE passage grave	Pomoideae (1piece)	2945±50	1263-1063
AA-25236	From the socket of a kerbstone by the entrance passage of the NE passage grave	Hazel (1piece)	3145±55	1508-1399
AA-25235	From the socket of a kerbstone by the entrance passage of the NE passage grave	Hazel (1piece)	3600±50	2035-1893
AA-25234	Cairn core	Hazel (1 piece)	3475±45	1883-1743
AA-25233	Cairn core	Hazel (1 piece)	3530±45	1933-1779
AA-25232	Cairn core	Hazel (1 piece)	3595±60	2036-1887
AA-25231	Cairn core	Hazel (1 piece)	3535±45	1938-1782
AA-25230	Cairn core	Hazel (1 piece)	5535±55	4459-4347

Balnuaran of Clava South ring cairn

AA-25229	Cairn core	Hazel (1 piece)	2420±45	756-404
AA-25228	Cairn core	Hazel (1 piece)	2770±45	991-849
AA-25227	Beneath outer ramp of the monument	Alder (1 piece)	2745±45	927-837
AA-25227	Beneath outer ramp of the monument	Hazel (1 piece)	2680±45	895-808

Appendix 10: Key to named fungal spore types

This is a draft version of a working key I developed during the thesis as a relatively rapid means of deciding whether a spore had previously been named. Many previously described but unamed spores are not included in this key. As such this key represents work in process and all identifications should be checked against reference material where available, the relevant publications or a mycologist.

1) Are spores hyaline (**2**) or pigmented (**7**)?

2) are spores segmented fusiform (**3**), spherical, with protuberances (**4**), ellipsoidal, verrucate (**5**), other (**6**)?(N.B. many spores may appear hyaline because they are immature, and so the pigmented section should also be checked).

3) Hyaline fusiform spores with between 7-15 transverse septa have been identified as species of *Geoglossaceae* by van Geel (T. 77A), (1978) and van der Wiel (T. 77B), (1982). Hawksworth *et al.* 1995, describe the ascospores as being brown pigmented.

4) Spherical spores with protuberences up to 3 μm in size, described by Clarke (1994) as *Inocybe* within this genus sections *Cortinatae, Petignosae, Marginatae* (Bon1987) are characterised by ellipsoidal spores with protuberences.

5) Ellipsoidal, with verrrucate surface identified by Clarke 1994 as *Melamspora* spp.

6) Other presently unidentifiable but may also be immature spores of other spp. so try pigmented section.

7) Pigmented (**8**)

8) Are spores septate (**8**), aseptate (**37**) ?

9) Are their one (**10**), two (**20**) or three or more septa (**25**).

10) If single septa is the spore symmetrical (**11**) or assymetrical, or with a basal hyaline cell (**16**) ?

11) Do spores possess a smooth wall (**12**) or is there evidence of faint scabrae, or second highly ornamented wall (**13**)?

12) There are many monoseptate symmetrical smooth walled microfossils, van Geel (1978) has attributed spores of this type to *Spadicoides bina* in peat sediments (T.98).

13) Is the spore scabrate to faintly scabrate (**14**) or is there a clear perisporium

with pronounced lobes (**15**)

14) Some *Delitschia* spp.have these characteristics they are large (c.28-50x 14-18 µm.), brown ellipsoidal spores with pores at their apices see Clarke (1994) types MOI008 and MOD002.

15) Bakker (1982) identifies oval brown spores constricted at the central septa, with an attached lobed perisporium outer wall as possible *Zopfia* spp e.g. T. 730.

16) Spore oval with a basal hyaline cell (**17**), or pyriform (**18**) or with verrucate decoration (**19**).

17) Spores with a basal hyaline cell which may have one or many septa are often attributed to *Brachyosporium* spp. (e.g. Clarke 1994 MOI006, MOM002)

18) Small pyriform spores with a single septa, terminal cell larger than basal cell, which often has a small scar or aperture at point of attachment, have been attributed to *Cladiosporium* spp, e.g. van Geel 1978, T.67.

19) Clarke (1994), identified a verrucate, pyriform spore as a *Cladosporium* spp.(MOI001)

20) Is the spore symmetrical (**21**) or bilaterally symetrical or assymetrical (often with one cell hyaline) (**24**)

21) Spore is polyhedral (**22**) or some other shape (**23**)

22) van Geel identified fusiform smooth walled polyhedral spores as *Diporotheca* spp. these have simple pores c.3 µm pores in diameter at the ends, may have a seperate perispore near apices (Hawksworth *et al.* 1995)

23) There are many as yet unidentified forms of fungal spore with two or more septa, found in palynological preparations. Some these are two septate forms of multiseptal forms such as *Brachyhosporium* spp.(24)

24) Spores with between one and many septa often fusiform and oval in shape with the first cell hyaline and occasionally between one and two apical pores are identified by both Clarke 1994 (DII003, DII004, DIM001, DIM003) and Kuhry 1985 (T.462) as *Brachyosporium* spp.

25) Does the spore have columar attachments (**26**) or not (**27**)

26) Brown verrucose spore with 4 columnar attachments, *Tetraploa aristata* T.89 (van Geel 1978), Clarke 1994 (MUI008)

27) Does spore consistently have three septa (**24**) or more (**29**)

24) Is spore verrucate (**25**) or smooth walled (**26**)?

25) Verrucate three septate spores with irregularly spaced chambers may be

Cladosporium spp., (e.g. TRI007, Clarke 1994).

26) Spore has bilateral symmetry (**27**) or one side is flat (**28**)

27) Smooth spore may if central chambers darker than outer, may be a *Chaetosphaerella* spp., (e.g. TRI010, Clarke 1994) , or *Brachyosporium* spp., (TRD00, Clarke 1994, T.462, Kuhry 1985), if chambers all brown and septa have simple pores then may be a *Spadicoides* spp.(TRI014, Clarke 1994).or *Trichocladium* (T.465 Kuhry 1985.)

28) Smooth walled assymetrical spore probably *Meliola c.f. niessleana* , T.14 see van Geel 1978, Kuhry 1985, Clarke 1994 (TRI012).

29) Septa all either transverse (**31**) or of several kinds longtitudinal, transverse, angular etc. (**30**)

30) Various *Alternaria* and *Pleospora* spp. have many different numbers and type of septa. see T.3b (van Geel 1978) and MUI005, MUI020 and MUI011 (Clarke 1995).

31) Spore either helical (**32**), forming flat sheets of many cells (**33**) or elongated (**34**)

32) Helical spores between c. 40-80 mm. in diam probably belong to the genus *Helicoon* see van Geel 1978, T. 30.

33) Septal columns arranged into up to four seperate columns arranged at angles to each other all joined to a basal cell. *Asterosporium* (MUP001, Clarke 1995). Or if arranged in flat sheets of many columns all adjacent (in a fan like arrangement), *Dichtyosporium* spp. (Hoaen 1999, DII004). Fruit bodies discoid in shape with numerous radiating septa often branching. *Microthyrium / Actinopeltis* spp.spp.(see T. 8 A-C van Geel 1978) and ASM016, ASM018, ASM019, ASM045, ASM048 (Clarke 1994).

34) Longitudinal spores with 3 or more septa, with rounded ends (**35**) or which appear broken at one or both ends (36)

35) Many fungal spore types fall into this category e.g. van Geel types 63, 22, *Lasiosphaeria* spp.. and *Herpotrichella* spp. (1978)), and Clarke 1994 MUI001, MUI002 and MUI007,*Helminthosporium, Stagonospora* and *Bactrodesmium* spp.

36) Many fungal spore types fall into this types see van Geel(1978) T. 25, *Clasterosporium;* T.51*Sporidesmium;* T.96A *Beltrania* spp.

37) Is spore surface perforated by many small pits (**38**) or not (**39**)

38) Ovoid polyaperturate spores, often dark brown or black in colour are often *Gelinspora* spp. see T.1., T.2. and T.526 (van Geel 1978, 1983), and ASP001, ASP006, ASP007 (Clarke 1995).

39) Spores with single longitudinal split (**40**) or no such split and may have

one or several pores (**43**).

40) Spores may be oblong or triangular in shape (**41**) or be Ovoid to fusiform (**42**)

41) Spores of this type fall into two groups *Sporomiella* type and *Coniochaeta.* Spores of *Sporomiella* type are more boxy in outline. (Davis 1987, T.6, T. 172 van Geel 1978, Kuhry 1985).

42) Within this group spores may have smooth walls or an outer wrinkled wall, often slightly assymetrical and generally fusiform (T.4*Anthostomella fuegiana;* T.44 *Xylaria* spp. van Geel 1978, van der Wiel 1982), (ASD012, ASD013 *Xylaria* spp. Clarke 1994).

43) Spores with ornamentation (**44**) or smooth walled (**52**).

44) Decoration takes the form of echinae (**45**), reticulate (**46**) other (**47**)

45) Small circular spores with a dense covering of echinae may represent *Lycoperdon* spp./*Myxomycetes* spp., (see ASI012 Clarke 1994)

46) Two genera of reticulate spores have been identified which include two types of *Sphaerodes* spp. (ASD004, ASD020), and also *Tilletia sphagni* (T.27). Tilletia sphagni spores are often found associated with *Sphagnum* in peats and are yellow or brown coloured and globular. *Sphaerodes* spp. are coprophilous and often dark brown, ovoid with two pores at the poles. (T.27 van Geel 1978, ASD004, ASD020 Clarke 1994).

47) Spores have scabrae (**48**), verrucate (**49**), longitudinal grooves (**50**), crenulate (**51**).

48) Elongated fusiform spores with scabrate decoration, denser in middle of spore to give the impression of a band*Cladosporium* spp. (ASI035, Clarke 1994).

49) Densely verrucate ovoid brown spore sometimes with an attached hyaline foot chamber, *Apiosordaria* spp. (ASI048 Clarke 1994).

50) Ovoid limoniform spore with two apical pores and several fine longitudinal grooves *Neurospora* spp.. (T.55C van Geel 1978, ASD027 Clarke 1994)

51) Flattened spores (actually hyphopodia) with crenulate margins and central single pores (points of attachment), *Gaeumannocyces* spp. (T.126, Pals 1980). *Entophylictis* (T.13 van Geel 1978) have been described from the literature.

52) Smooth walled sporess with attachments (**53**) or no attachments (**56**)

53) Attachment takes the form of a foot cell or hilar appendage (**54**) or suspensor (**55**)

54) *Histoplasma capsulatum* (ASI002, Clarke 1994) is a spherical grey spore often with a attached foot cell. Fossil examples of Spp.. of the Bolbitaceae and Coprinaceae are small spores, often with an a hilar appendage at the pole and a pore at the opposite pole (ASM002, ASM009, Clarke 1994).

55) Large spherical spores yellow-brown with a long suspensor are usually derived from the Endogenaceae. E.g. T.207 van Geel *et al.* 1988 and ASI020 Clarke 1994.

56) Spores have no (**57**), 1 (**58**), or 2 or more pores (**59**)

57) Most identifiable taxa within this group of smooth walled, brown spores with no pores or septa are derived from the *Sordariales* and *Dothidiales*, and have been assigned to taxa on the basis of shape.

Description: Small brown spores, often oblong or or triangular in shape, with rounded corners. ASI042, *Sporomia*, Clarke 1994

Description: Limoniform, brown spores with smooth surface, and umbonate poles bilaterally flattene. Type 7A, *Chaetomium* spp. van Geel 1978, 1988, Kuhry 1985

Description: Ellipsoidal, smooth walled brown spore, with a slight truncation at one pole. T.169, *Sordariales cf. Tripterospora* (van Geel *et al.* 1983 & Clarke 1994, ASI054, ASI070)

Description: Ovoid smooth walled brown spore, with a slight truncation at one pole, other pole umbonate in form. *Sordaria* spp. (ASI037, ASI039, Clarke 1994)

Description: Ovoid, smooth walled brown spore. *Sordaria* spp. (ASI052, Clarke 1994)

Description: Ovoid, smooth walled brown spore, with an occasional simple apical pore. *Sordaria* spp. (ASI072, Clarke 1994)

Description: Ovoid, smooth walled brown spore, with a slight truncation at one pole. very thick dark wall. *Sordaria* spp. (ASI079, Clarke 1994)

58a) In this section all but three types (**58b**) are derived from the *Sordariales*

Description: Brown smooth walled elongated ovoid bilaterally symmetrical spores. One pole is truncated, occasionally to one side of the spore. The other pole is smoothly rounded with a simple pore c. 1.5. mm.in diameter. (T. 466, *Sordariales c.f. Podospora* spp. Kuhry 1985)

Description: Dark brown bilaterally symmetrical spore, one truncate pole to which a hyaline foot cell may be attached, the other pole is smoothly rounded and has a simple pore c. 1 mm in diameter, often slightly off centre. The truncate pole also contains a central pore c. 1 mm in diameter. 112A B C,

Sordariales Cercophora spp. (van Geel 1978, 1983, van der Wiel 1982, Bakker 1982)

Description: Dark brown ellipsoidal spores, smooth surface, single apical pore c. 1.5 diam. Size range 18-20x 10-11 1 mm. (55A, *Sordaria* spp., van Geel 1978, 1983, Bakker 1982).

Description: Dark brown bilaterally symmetrical spore, One pole is truncated and contains a central simple pore c. 3 mm in diameter. the opposite pole is umbonate. (ASM008 *Sordaria* spp., Clarke 1994)

Description: Ovoid, smooth walled brown spore, with one truncated pole which has a single simple pore c. 1 mm. in diameter, other pole narrowly rounded. (ASM012, *Sordaria* spp., Clarke 1994 (c.f. type 7A above))

Description: Sub-ovoid, smooth walled brown spore, with one truncated pole which has a single simple pore c. 1 mm. in diam. (ASM013, *Sordaria* spp.Clarke 1994)

Description: Ovoid, smooth walled brown spore, with one narrow truncated pole which has a single simple pore c. 1 mm. in diameter, other pole smoothly rounded. (ASM015,*Sordaria* spp.Clarke 1994)

Description: Ellipsoidal, smooth walled brown spore, with one truncated pole other pole tapered with a single simple pore c. 1 mm. in diameter. (ASM021, *Sordaria* spp. Clarke 1994)

Description: Ellipsoidal, smooth walled brown spore, with a single simple pore c. 1 mm. in diam, 4mm. below the pole. (ASM024, *Sordaria* spp. Clarke 1994)

Description: Ovoid, smooth walled brown spore, with a single umbonate pole, the single simple pore is located just below the pole c. 1 mm. in diameter. (ASM025, *Sordaria* spp. Clarke 1994)

Description: Ellipsoidal, smooth walled dark brown spore, with a single simple pore c. 1 mm. in diam, just below the pole.(ASM026, *Sordaria* spp. Clarke 1994)

Description: Ovoid, smooth walled brown spore, with one truncated and one tapered pole, the single simple pore (c. 1 mm. in diameter), is located just below the tapered pole .(ASM029, *Sordaria* spp. Clarke 1994)

Description: Ovoid, smooth walled brown spore, the single simple pore (c. 1 mm. in diameter), is located in the middle of the spore. (ASM031, *Sordaria* spp. Clarke 1994)

Description: Ovoid, assymetrical smooth walled brown spore, one pole tapers sharply to one side forming a rounded apex, the single simple pore (c. 1 mm. in diameter), is located at the opposing pore. (ASM041, *Sordaria* spp.

ate.(ASD016, *Sordaria* spp., Clarke 1994)

Description: Limoniform smooth walled brown/ dark brown spore, with simple poles located at each pole. (ASD017, *Sordaria* spp., Clarke 1994)

Description: Ovoid smooth walled brown spore, with simple apertures located at each pole c.1 mm. Both poles are umbonate and one is also truncate. (ASD024, *Sordaria* spp., Clarke 1994)

Description: Ellipsoidal, smooth walled brown spore, simple apertures are located at each pole. (ASD026, *Sordaria* spp., Clarke 1994)

Description: Ellipsoidal, smooth walled brown spore, simple apertures are located at each pole. (ASD030, *Sordaria* spp., Clarke 1994)

Description: Ovoid smooth walled brown spore, with simple apertures located at each pole c.1 mm. One pole is rounded and one is truncated. (ASD031, *Sordaria* spp., Clarke 1994)

Description: Ovoid smooth walled brown spore, with simple apertures located at each pole c.1 mm. One pole is rounded and one is truncated. (ASD035, *Sordaria* spp., Clarke 1994)

Description: Ovoid, smooth walled brown spore, a simple aperture is located at the tapered pole these spores also display between one and two other pores located at random. (ASP010, *Sordaria* spp., Clarke 1994)

62) Description: Fusiform, smooth walled grey-light brown spore, with simple pores located at each aperture.*Ustulina* spp., (see T.117 Pals 1980 and ASD038 Clarke 1995)

Appendix 11: Glossary of abbreviations

TLP: Total land pollen includes pollen and cryptogram spores
TP: Total pollen land pollen minus cryptogram spores
NPF: Non-pollen microfossils includes fungal spores, discrete algal microfossils.
SWPG: Southwest passage grave at Balnuaran of Clava
NEPG: Northeast passage grave at Balnuaran of Clava
CRC: Central ring cairn at Balnuaran of Clava
SRC: Southern Ring cairn at Balnuaran of Clava

Bibliography

Aaby, B. 1983. "Forest development, soil genesis and human activity illustrated by pollen and hypha analysis of two neighbouring podzols in Draved forest, Denmark." *Denmark Geologiske Undersøgelse* . II 114:1-111.

Aaby, B. 1986. "Trees as anthropogenic indicators in regional pollen diagrams from Eastern Denmark," in *Anthropogenic Indicators in Pollen Diagrams.* Edited by K.E. Behre. Rotterdam: A.A. Balkema. pp. 73-93

Ahmed, S. E. and R.F. Cain. 1972. "Revision of the genera Sporomia and Sporomiella." *Canadian journal of Botany*. 50:419-477.

Akeret, O., J. N. Haas, U. Leuzinger & S. Jacomet 1999 "Plant macrofossils and pollen in goat/sheep faeces from the Neolithic lake-shore settlement Arbon Bleiche 3, Switzerland." *Holocene* 9: 175-182

Aitken, M.J. 1990. *Science Based Dating in Archaeology*. London: Unwin.

Andersen, S.T. 1970. "The relative pollen productivity and pollen representation of North European trees and correction factors for tree pollen spectra." *Danmarks Geologiske Undersøgelse* 2 80:1-99.

Andersen, S.T. 1973. "The differential pollen productivity of trees and its significance for the interpretation of a pollen diagram from a forested region." in *Quaternary Plant Ecology*. Edited by H.J.B. Birks and R.G. West. Oxford: Blackwell. pp. 109-115.

Andersen, S.T. 1978. "The identification of wild grass and cereal pollen." *Danmarks Geologiske Undersøgelse* Årbog. pp.69-92.

Andersen, S.T. 1979. "Brown earth and podzol: soil genesis illuminated by microfossil analysis." *Boreas* 8:59-73.

Andersen, S.T. 1984. "Stages in soil development reconstructed by evidence from hypha fragments, pollen, and humus contents in soil profiles." in *Lake Sediments and Environmental History: studies in honour of Winifred Tutin.* Edited by E.Y. Haworth and J.W.G. Lund. Minneapolis: University of Minnesota Press. pp. 215-316.

Andersen, S.T. 1988. "Pollen spectra from the double passage grave, Klekkendehøj, on Møn." *Journal of Danish Archaeology* 7:77-82.

Armit, I. 1996. "The transition to agriculture 3: Scotland." in *The Early Prehistory of Scotland.* Edited by T. Pollard and A. Morrison. Edinburgh: Edinburgh University Press. pp.280-290.

Ashmore, P.J. 1996. *Neolithic and Bronze Age Scotland.* London:B.T. Batsford Ltd.

Bakker, M. and D.G. van Smeerdijk 1986 "A palaeoecological study of the late Holocene section from "Het Ilperveld", Western Netherlands." *Review of Palaeobotany and Palynology.* 36:95-163.

Barber, J. 1990. "Scottish burnt mounds: variations on a theme." in *Burnt Offerings: International Contributions to Burnt Mound Archaeology.* Edited by V. Buckley. Dublin: Wordwell Ltd. pp. 98-106.

Barber, K.E. 1981. *Peat Stratigraphy and Climatic Change.* Rotterdam: A.A. Balkema.

Barber, K.E., Chambers, F.M., Maddy, D., Stoneman, R. and J.S. Brew. 1994. "A sensitive high-resolution record of late Holocene climatic change from a raised bog in northern England." *The Holocene* 4:198-205.

Barcham, R.C. 1981. "A lost radiocarbon date for Shetland." *Proceedings of the Society of Antiquaries of Scotland* 110:502-6.

Barclay, G.J. 1983. "Sites of the third millenium bc to the first millenium bc at North Mains, Strathallan, Perthsire." *Proceedings of the Society of Antiquaries of Scotland* 113:122-281.

Barclay, G.J. 1992. "Are the Clava type 'passage graves' really passage graves? a reconsideration of the nature and associations of the Clava passage graves and ring cairns." in *Vessels for the Ancestors.*: Edited by N. Sharples and A. Sheridan. Edinburgh: Edinburgh University Press. pp. 77-83.

Barclay, G.J. 1990. "The clearing and partial excavation of the cairns at Balnuaran of Clava, Invernes-shire, by Miss Kathleen Kennedy, 1930-31." *Proceedings of the Society of Antiquaries of Scotland* 120:17-32.

Barclay, G.J. and C.J. Russell-White Editors. 1993. "Excavations in the ceremonial complex at Balfarg/Balbirnie, Glenrothes Fife." *Proceedings of the Society of Antiquaries of Scotland* 123:43-210.

Barclay, G.J. 1997. "The Neolithic." in *Scotland: Archaeology and Environment 8000 BC- AD 1000.* Edited by K. Edwards and I. Ralston London: John Wiley & Sons. pp. 127- 151.

Barron, M. and G. Bush. 1975. "Some local botany." in *The Hub of the Highlands.* Edited by L. Maclean. Lerwick: The Shetland Times Ltd. pp. 24-55.

Batten, D.J. 1973. "Use of palynologic assemblage-types in Wealden correlation." *Palaeontology* 16:1-40.

Batten, D.J. 1982. "Palynofacies, palaeoenvironments, and petroleum." *Journal of Micropalaeontology* 1:107-14.

Baxter, M.J. 1994. *Exploratory Multivariate Analysis in Archaeology*. Edinburgh: Edinburgh University Press.

Behre, K.E. 1981. "The interpretation of anthropogenic indicators in pollen diagrams." *Pollen et Spores* 23:225-245.

Behre, K.E. Editor. 1986. *Anthropogenic Indicators in Pollen Diagrams*. Rotterdam: A.A. Balkema.

Bennett, K. 1994. "Tephra geochemistry: a comment on Hunt and Hill." *Holocene*, 4:435-438.

Bennett, K. 1995 "*Annotated catolgue of pollen and Pteridophyter spore types of British Isles*" Dept. of Plant Sciences, University of Cambridge.

Bennett, K., S. Boreham, M.J. Sharp, and V.R. Switsur. 1992. "Holocene history of environment, vegetation and Human settlement on Catta Ness, Lunnasting, Shetland." *Journal of Ecology* 80:241-273.

Bennett, K., S. Boreham, K. Hill, S. Packman, M.J. Sharp, and V.R. Switsur. 1993. "Holocene environmental history at Gunnister north Mainland, Shetland." in *The Quaternary of Shetland Field Guide*. Edited by J. Birnie, J. Gordon, K. Bennett, and A. Hall. Cambridge: Quaternary Research Guide. pp. 83-98.

Bennett, K. and M.J. Sharp. 1993. "Holocene vegetation and environment." in *The Quaternary of Shetland*. Edited by J. Birnie, J. Gordon, K. Bennett, and A. Hall. London: Quaternary Research Association. pp. 18-22.

Berglund, B.E. 1986. "Pollen analysis and pollen diagrams," in *Handbook of Holocene Palaeoecology and Palaeohydrology*. Edited by B. E. Berglund. London: John Wiley & Sons Ltd. pp. 455-483.

Berglund, B.E. 1988. "The cultural landscape during 6000 years in south Sweden-an interdisciplinary study." in *The Cultural Landscape-Past, Present and Future*. Edited by H.H. Birks, H.J.B. Birks, K.E. Kaland, and D.E. Moe. Cambridge: Cambridge University Press. pp. 251-254.

Berry, R.J. and J.L. Johnston. 1980. *The Natural History of Shetland*. London: Collins.

Birks, H.J.B. 1986. "Late Quaternary biotic changes in terrestrial and lacustrine environments, with particular reference to north-west Europe." in *Handbook of Holocene Palaeoecology /and Palaeohydrology*. Edited by B.E. Berghlund. London: John Wiley & Sons Ltd. pp. 3-65.

Birks, H.J.B. and H.H. Birks. 1980. *Quaternary Palaeoecology*. London: Edward Arnold.

Birks, H.J.B. and A.D. Gordon. 1985. *Numerical Methods in Quaternary Pollen Analysis*. London: Academic Press.

Birnie, J. 1984 "Trees and shrubs in the Shetland Islands: evidence for a post-glacial climatic optimum?" in *Climatic changes on a yearly to Millenial basis.* Edited by N.A. Morner & W. Karlen. pp.155-161.

Birnie, J., J. Gordon, K. Bennett, and A. Hall.(editors) 1993*The Quaternary of Shetland Field Guide*. Cambridge: Quaternary Research Guide.

Birks, H.H., H.J.B. Birks, K.E. Kaland, and D. Moe. Editors. 1988. *The Cultural Landscape-Past, Present and Future*. Cambridge: Cambridge University Press.

Blackford, J.J. 1993. "Peat bogs as sources of proxy climate data: past, approaches and future research." in *Climate Change and Human Impact on the Landscape*. Edited by F.M Chambers. London: Chapman and Hall. pp.47-56.

Bradley, R. 1978. *The Prehistoric Settlement of Britain*. London: Routledge and Kegan Paul.

Bradley, R. 1991. "Rock art and the perception of landscape." *Cambridge Archaeological Journal* 1:77-101.

Bradley, R. 1996. *Excavation at Balnuaran of Clava 1994 and 1995*. Department of Archaeology, University of Reading.

Bradley, R. forthcoming. *The Good Stones: A new investigation of the Clava cairns*. Edinburgh: Society of Antiquaries of Scotland Monograph series.

Bradley, R., J. Harding and M. Mathews 1993. "The siting of prehistoric rock art in Galloway, Southwest Scotland." *Proceedings of the Prehistoric Society* 59: pp. 269-283.

Brasier, M.D. 1980. *Microfossils*. London: Allen & Unwin.

Brenchley, P.J. 1990. "Biofacies." in *Palaeobiology: a synthesis*. Edited by D.E.G. Briggs. Oxford: Blackwell Scientific Publications. pp. 1-9.

Briffa, K. and T. Atkinson 1997. "Reconstructing Late-Glacial and Holocene climates." in *Climates of the British Isles: Present, Past and Future*. Edited by M.Hulme and E. Barrow. London: Routledge. pp.84-107.

British Geological Survey. 1981. *Central Shetland. Solid 1:63630*. Institute of Geological Sciences.

British Geological Survey. 1981. *Central Shetland, Drift 1:63630*. Institute of Geological Sciences.

British Geological Survey. 1997. "Fortrose, Scotland sheet 84W, 1:50 000" *Drift and Solid Geology*. Institute of Geological Sciences.

Buckley, V. Editor. 1990. *Burnt Offerings: International Contributions to Burnt Mound Technology*. Dublin: Wordwell Academic Publications.

Bunting, M. J. 1994. "Vegetation history of Orkney, Scotland; pollen records from two small basins in west Mainland." *New Phytologist* 128:771-792.

Bunting, M. J. 1996. "The development of heathland in Orkney, Scotland: Pollen records from Loch of Knitchen (Rousay) and Loch of Torness (Hoy)." *The Holocene* 6:193-212.

Burgess, C. 1985. "Population, climate and upland settlement." in *Upland Settlement in Britain*, Edited by D. Spratt and C. Burgess. Oxford: BAR. British Series 143. pp.195-229.

Burgess, C. 1989 "Volcanoes, catastrophe and the global crisis of the late Second Millenium BC." *Current Archaeology* 117:325-329.

Burl, A. 1972. "Stone circles and ring cairns." *Scottish Archaeological Forum* 4:31-47.

Butler, S. 1998. "Climate, ecology and land use since the last ice age." in *The Shaping of Shetland*. Edited by V. Turner. Lerwick: Shetland Times Ltd. pp.3-11.

Calder, C.S.T. 1952. "Report on the excavation of a Neolithic temple in the parish of Sandsting, Shetland." *Proceedings of the Society of Antiquaries of Scotland* 84:185-205.

Calder, C. S.T. 1955-6. "Stone age house sites in Shetland." *Proceedings of the Society of Antiquaries of Scotland* 89:340-397.

Calder, C. S.T. 1962. "Neolithic structures in Shetland." in *The Northern Isles.* Edited by F. T. Wainwright. Edinburgh: Nelson. pp.26-43.

Calder, C. S.T. 1963-64. "Cairns, Neolithic houses and burnt mounds in Shetland." *Proceedings of the Society of Antiquaries of Scotland* 96:37-86.

Canter, M. 1998. "Prehistoric sites in the Shetland landscape: A GIS study of Mainland, Shetland." in *The Shaping of Shetland.* Edited by V. Turner. Lerwick: Shetland Times Ltd. pp.47-60.

Casparie, W.A., and W. Groenman-van Waateringe. 1980. "Palynological analysis of Dutch barrows." *Palaeohistoria* 22:7-65.

Christensen, M. 1989. "A view of fungal ecology." *Mycologia.* 81:1-19.

Chambers, F.M. 1988. "Archaeology and the flora of the British Isles: the Moorland experience." in *Archaeology and the Flora of the British Isles.* Edited by M. Jones. Oxford: Oxford University Committee for Archaeology Monograph no. 14. pp.107-115.

Clark, R.L. 1982. "Point count estimation of charcoal in pollen preparations and thin sections of sediments." *Pollen et Spores* XXIV:523-535.

Clarke, C.M. 1994. *Fungal Spores as Palaeoenvironmental Indicators of Anthropogenic Activity.* unpublished Ph.D. University of Edinburgh.

Clarke, C.M. in press. *A Morphological Recording System for Fungal Microfossils.* Palaeoenvironmental Research Group Working Papers No 1. Edinburgh: University of Edinburgh.

Clarke, P.A. 1995. *Observation of Social Change in Prehistoric Orkney and Shetland Based on a Study of the Types and Context of Coarse Stone Artefacts.* Unpublished Mlitt. University of Glasgow.

Clarke, D.V., and N. Sharples. 1985. "Settlements and Subsistence in the Third Millenium BC." in *The Prehistory of Orkney.* reprint. Edited by C. Renfrew. Edinburgh: Edinburgh University Press. pp.54-82.

Coles,B., and J.M.Coles. 1986. *Sweet track to Glastonbury: The Somerset Levels in Prehistory.* London: Thames and Hudson.

Collins, J.G., B.T.D. D'Sylva, and P.M. Latter. 1978. "Microbial populations in peat." in *Production Ecology of British Moors and Montane Grasslands.* Edited by O.W. Heal and D.F. Perkins. Berlin: Springer. pp.94-112.

Combaz, A. 1964. "Les Palynofacies." *Revue de Micropalaeontologie* 7:205-218.

Conway, V.M. 1948. "Von Post's work on climatic rhythms." *New Phytologist* 47:117-147.

Cracknell, S., and B.B. Smith. 1983. "Archaeological investigations at Mavis Grind." *Glasgow Journal of Archaeology* 10:13-39.

Cronberg, G. 1986. "Blue green algae, Green algae and Chrysophyceae in sediments." in *The Handbook of Holocene Palaeoecology and Palaeohydrology.* Edited by B.E. Berglund. London: John Wiley & Sons. pp.507-526.

Cross, A.T., G.G. Thompson, and J.B. Zaitzeff. 1966. "Source and distribution of palynomorphs in bottom sediments, southern part of Gulf of California." *Marine Geology* 4:467-524.

Cushing, E.J. 1964. "Redeposited pollen in Late Wisconsin pollen spectra fromeast-central Minnesota." *American Journal of Science* 262:1075-88.

Cushing, E. J. 1967. "Evidence for differential pollen preservation in Late Quaternary sediments in Minnesota." *Review of Palaeobotany and Palynology* 4:87-101.

Darrell, J.H.N. 1973. *Statistical Evaluation of Palynomorph Distribution in the Sedimentary Enviroments of the Modern Mississipi River Delta.* Unpublished Ph.D. Louisiana State University.

Davidson, D.A, and I. Simpson 1994. "Soils and landscape history: case studies from the Northern Isles of Scotland." in *The History of Soils and Field Systems*. Edited by S. Foster and T. Smout. Aberdeen: Aberdeen Scottish Cultural Press. pp.66-75.

Davis, O.K. 1987. "Spores of the Dung Fungus Sporomiella: Increased Abundance in Historic Sediments and before Pleistocene Megafaunal Extinction." *Quaternary Research* 28:290-294.

Dawson, A.G., D. Long, and D.E. Smith. 1988. "The Storegga slides: evidence from eastern Scotland for a possible Tsunami." *Marine Geology* 82:271-276.

Dawson, A.G., D.E. Smith. and D. Long, 1990. "Evidence for a tsunami from a Mesolithic site in Inverness, Scotland." *Journal of Archaeological Science* 17:509-512.

Delcourt, P.A., and H.R. Delcourt. 1980. "Pollen preservation and Quaternary environmental history in the Southeastern United States." *Palynology* 4:215-231.

Dickson, C. 1994. "The decline of woodland in Orkney: Early Neolithic to Late Iron Age." Paper given at the AEA conference Bradford, W. Yorkshire.

Dimbleby, G.W. 1961a. "Soil Pollen Analysis." *Journal of Soil Science* 12:1-12.

Dimbleby, G.W. 1961b. "Transported Material in the Soil Profile." *Journal of Soil Science* 12:12-22.

Dimbleby, G.W. 1962. *The Development of British Heathlands and their Soils.* Oxford: Oxford University Press.

Dimbleby, G.W. 1985. *The Palynology of Archaeological Sites.* London: Academic Press.

Dix, J.N. and J. Webster. 1995. *Fungal Ecology.* London: Chapman and Hall.

Dimbleby, G.W. and Evans, J.G. 1974. "Pollen and land snail analysis of calcareous soils." *Journal of Archaeological Science* 1:117-133.

Dix, J.N. and J. Webster. 1995. *Fungal Ecology.* London: Chapman and Hall.

Dockrill, S. Editor. 1992. *The South Nesting Palaeolandscape Project.* Bradford: University of Bradford.

Dockrill, S. and I. A. Simpson. 1994. "The identification of prehistoric anthropogenic soils in the Northern Isles using an integrated sampling methodology." *Archaeological Prospection* 1:75-92.

Dockrill, S., J. Bond, and T.P. O'Connor. 1998. "Beyond the burnt mound: The South Nesting Palaeolandscape project." in *The Shaping of Shetland.* Edited by V. Turner. Lerwick: The Shetland Times Ltd. pp.61-83.

Dodgshon, R.A. 1988. "The ecological basis of Highland peasant farming, 1500-1800 A.D." in *The Cultural Landscape: Past, Present and Future.* Edited by H.H. Birks, H.J B. Birks, P.E. Kaland, and D. Moe. Cambridge: Cambridge University Press. pp.139-152.

Dugmore, A. 1989. "Icelandic volcanic ash in Scotland." *Scottish Geographical Magazine* 105 168-172.

Dugmore, A., and A. Newton. 1996. "Acid digestion technique for the extraction and concentration of Volcanic Tephra from peat.": http://www.geo.ed.ac.uk/tephra/acid1.html.

Dumayne, L., R. Stoneman, K. Barber, and D. Harkness. 1995. "Problems associated with correlating calibrated radiocarbon dated pollen diagrams with historical events." *The Holocene* 5:118-123.

Durno, S. E. 1956. "Certain aspects of vegetational history in North East Scotland." *Scottish Geographical Magazine* 72:176-184.

Edwards, K.J. 1979a. "Palynogical and temporal inference in the context of prehistory, with special reference to the evidence from Lake and peat deposits." *Journal of Archaeological Science* 6:255-270.

Edwards, K.J. 1979b. "Environmental impact in the Prehistoric period." *Scottish Archaeological Forum* 9:27-42.

Edwards, K.J. 1981. "The seperation of *Corylus* and *Myrica* pollen in modern and fossil samples." *Pollen et Spores* 23:205-18.

Edwards, K.J. 1990. "Fire and the Scottish Mesolithic: evidence from microscopic charcoal." in *Contributions to the Mesolithic in Europe.* Edited by P.M. Vermeersch and P. van Peer. Leuven: Leuven University Press pp.71-79.

Edwards, K.J. 1996. "A Mesolithic of the Western and Northern Isles of Scotland evidence from pollen and charcoal." in *The Early Prehistory of Scotland.* Edited by T. Pollard and A. Morrison. Edinburgh: Edinburgh University Press. pp.23-39.

Edwards, K.J. and I.M. Ralston. 1984. "Postglacial hunter-gatherers and vegetational history in Scotland." *Proceedings of the Society of Antiquaries of Scotland* 114:15-34.

Edwards, K.J. and C.J. McIntosh. 1988. "Improving the detection rate of cereal type pollen grains from *Ulmus* decline and earlier deposits from Scotland." *Pollen et Spores* 30:179- 188.

Edwards, K.J. and A.G. Moss. 1993. "Pollen data from the Loch of Brunatwatt, west Mainland." in *The Quaternary of Shetland Field Guide*. Edited by J. Birnie, G. Gordon, K. Bennett, and A. Hall. Cambridge: Quaternary Research Association. pp.126-129.

Edwards, K.J. and G. Whittington. 1997. "Vegetation change. "in *Scotland:Environment and Archaeology, 800 BC-AD100*". Edited by K.J. Edwards and I. Ralston. London: John Wiley & Sons. pp.63-83.

Ellis, M.B. 1971. *Dematiaceous Hyphomycetes*. London: Commonwealth Agricultural Bureaux.

Ellis, M.B. and J. Ellis. 1985. *Microfungi on Land Plants: An Identification Handbook*. Portland:Timber Press. USA.

Ellis, M.B. and J. Ellis. 1988. *Microfungi on Miscellaneous Substrates: An Identification Handbook*. London: Croom Helm.

Elsik, W.C. 1969. "Late Neogene Palynomorph Diagrams, Northern Gulf of Mexico." *Transactions - Gulf Coast Association of Geological Societies* XIX:509-28.

Elsik, W.C. 1976a. "Fossil fungal spores." in *The Fungal Spores*. Edited by D.J. Weber and W.M. Hess. New York: John Wiley & Sons. pp.849-862.

Elsik, W.C. 1976b. "Microscopic Fungal Remains and Cenozoic Palynostratigraphy." *Geoscience and Man* XV:115-120.

Elsik, W.C. 1986a. "Fungal palynomorphs recovered from recent river deposits, Luangwa Valley, Zambia." *Palynology* 10:35-60.

Elsik, W.C. 1986b. "Palynology of a Late Pleistocene Giant Ground Sloth Locality, Southwest Harris County, Texas." *Pollen et Spores* XXVIII:77-82.

Elsik, W.C. and J. Jansonius. 1974. "New genera of Paleogene fungal spores." *Canadian Journal of Botany* 52:953-958.

Erdtman, G. 1924. "Studies in the micropalaeontology of postglacial deposits in Northern Scotland and the Scotch Isles with especial reference to the history of woodlands." *Journal of the Linnean Society, Botany* 46:451-504.

Fægri, K. and J. Iversen. 1975. *Textbook of Pollen Analysis*. 3rd. edition. Oxford: Blackwell Scientific Publications.

Fægri, K. and J. Iversen. 1989. *Textbook of Pollen Analysis*. IV edition. Chichester: John Wiley & Sons.

Fairweather, A.D. and I.M. Ralston. 1993. "The Neolithic timber hall at Balbridie, Grampian Region, Scotland: a preliminary note on dating and plant macrofossils." *Antiquity* 67:313-323.

Farr, K.M. 1988. *Palynomorph and Palynodebris Distributions in Modern Estuarine Sediments*. unpublished Ph.D. University of Aberdeen.

Fenton, A. 1978. *The Northern Isles: Orkney and Shetland*. East Linton: John Donald Ltd.

Firth and Smith. 1993. "Holocene sea level changes in Shetland." in *The Quaternary of Shetland*. Edited by J. Birnie, J. Gordon, K. Bennett, and A. Hall. London: Quaternary Research Association. pp. 16-18.

Fojut, N. 1985. "Some thoughts on the Shetland Iron Age." in *Shetland Archaeology*. Edited by B. Smith. Lerwick: Shetland Times. pp.47-85.

Fojut, N. 1994. *A Guide to Prehistoric and Viking Shetland*. Lerwick: Shetland Times Ltd. 3rd edition

Foster, S. and T.C. Smout. Editors. 1994. *The History of Soils and Field Systems*. Aberdeen: Scottish Cultural Press.

Frankland, J.C. 1975. "Fungal decomposition of leaf litter in a deciduous wood." in *Biodegradation et Humification*. Edited by G.K. Kilbertus, O. Reisinger, A. Mourey, and J.A. Cancella da Fonseca. London: Academic Press. pp.30-36.

Futty, D.W., and W. Towers. 1982. *Northern Scotland Soil and Land Capability for Agriculture*. Aberdeen: University Press.

Gaillard, M.J., H.J.B. Birks, U. Emanuelsson, and B.E. Berglund. 1992. "Modern pollen/land-use relationships as an aid in the reconstruction of past land uses and cultural landscapes: an example from south Sweden." *Vegetation History and Archaeobotany* 1:3-17.

Godwin, H. 1981. *The Archives of the Peat Bogs*. Cambridge: Cambridge University Press.

Godwin, H. 1956. *The History of the British Flora*. 1st. editionCambridge: Cambridge University Press.

Griffin, D.M. 1972. *Ecology of Soil Fungi.* London: Chapman and Hall.

Groenman-van Waateringe, W. 1986. "Grazing possibilities in the Neolithic of the Netherlands based on palynological data." in *Anthropogenic Indicators in Pollen Diagrams.* Edited by K.E. Behre. Rotterdam: A.A. Balkema. pp.187-203.

Gunson, A. R. 1975. "The vegetation history of north east Scotland." in *Quaternary Studies in North East Scotland.* Edited by A.D. Gemmell.Aberdeen: Department of Geography, University of Aberdeen. pp.61-73.

Habib, D. 1979. "Sedimentary origin of North atlantic palynofacies." in *Deep Drilling Results in the Atlantic Ocean: Continental Margins and Palaeoenvironment.* American Geophyscial Union. pp. 420-37

Hall, A.M. 1993. "Clettnadal, West Burra." in *The Quaternary of Shetland.* Edited by J.Birnie, J. Gordon, K. Bennett, and A. Hall. London: Quaternary Research Association. pp.48-50.

Hall, V.A. 1989. "A study of the modern pollen rain from a reconstructed 19th century farm." *Irish Naturalists Journal* 23:82-92.

Hamilton, J.R.C. 1956. *Excavations at Jarlshof, Shetland.* Edinburgh: HMSO.

Harding, A.F. 1982. *Climatic Change in Later Prehistory.* Edinburgh: Edinburgh University Press.

Havinga, A.J. 1963. "A palynological investigation of soil pollen profiles developed in cover sand." *Meded. Landsbhoogesch* 63:1-93.

Havinga, A.J. 1964. "A 20 year experiment into the differential corrosion susceptibility of pollen and spores in various soil types." *Pollen et Spores* 26:541-558.

Hawksworth, D.L., P.M. Kirk, B.C. Sutton, and D.N. Peglar. 1995. *Ainsworth and Bisby's Dictionary of the Fungi.* eighth edition. London: CAB International.

Hedges, J.W. 1977. "Excavation of two Orcadian burnt mounds at Liddle and Beaquoy." *Proceedings of the Society of Antiquaries of Scotland* 106:39-98.

Hedges, J.W. 1986. "Bronze age structures at Tougs, Burra Isle, Shetland." *Glasgow Archaeological Journal* 13:1-43.

Hedges, J.W., and G.A. Parry. 1980. "A Neolithic multiple burial from Sumburgh, Shetland." *Glasgow Archaeological Journal* 7:15-26.

Henshall, A.S. 1963. *The Chambered Tombs of Scotland.* Volume One. Edinburgh: Edinburgh University Press.

Hodder, M.A., and L H. Barfield. Editors. 1991. *Burnt Mounds and Hot Stone Technology*. Sandwell: Sandwell Metropolitan Borough Council.

Hoppe, G. 1965. "Submarine peat in the Shetland Islands." *Geografiska Annaler* 47A:195-203.

Hulme, P.D., and J. Shirriffs. 1994. "The Late-glacial and Holocene vegetation of the Lang Lochs mire area, Gulberwick Shetland: a pollen and macrofossils investigation." *New Phytologist* 128:793-806.

Hunt, C.O., and G.M. Coles. 1988. "The application of palynofacies analysis to geoarchaeology." in *Science and Archaeology Glasgow 1987*. Edited by E.A. Slater and J.O. Tate. Oxford: BAR. British Series Vol. 196. pp.473-484.

Hunt, D. 1987. *Early Farming Communities in Scotland*. Oxford: BAR. British Series Vol. 159.

Hunter, J. 1996. *Fair Isle: The Archaeology of an Island Community*. Edinburgh: HMSO.

Ingold, C.T. 1965. *Spore Liberation*. Oxford: Clarendon Press.

Ingold, C.T. 1971. *Fungal Spores: Their Liberation and Dispersal*. Oxford: Clarendon Press.

Ingold, C.T. and H.J. Hudson 1993. *The Biology of the Fungi*. London: Chapman and Hall.

Iversen, J. 1941. "The influence of prehistoric man on vegetation." *Danmarks Geologiske Undersogelse*. Series 2. 6:1-25.

Jacobson, G.L. and R.H.W. Bradshaw 1981. "The selection of sites for paleovegetational studies." *Quaternary Research* 16:80-96.

Johansen, J. 1975. "Pollen Diagrams from the Shetland and Faroe Islands." *New Phytologist* 75:369-387.

Johansen, J. 1976. "The age of the introduction of *Plantago lanceolata* to the Shetland Islands." *Danmarks Geologiske Undersøgelse Yearbook* 45-48.

Johansen, J. 1985. "Studies in the vegetational history of the Faroe and Shetland Islands." *Annales Societotis Scientiorum Faeroensis* Supplementum XI.

Jones, M.J. 1988 "The arable field: a botanical battleground." in *Archaeology and the Flora of the British Isles*. Edited by Martin Jones. Oxford: Oxford Committee of Archaeology. pp.86-92.

Jones, A.M. 1997. *A Biography of Ceramics: Food and Culture in Late Neolithic*

Orkney. unpublished Ph.D. University of Glasgow.

Jowsey, P.C. 1966. "An improved peat sampler." *New Phytologist* 65:489-493.

Kaminski, J. 1996. *Charcoal Identifications from the Balnuaran of Clava (interim report)*. Department of Archaeology, University of Reading.

Keatinge, T.H., and J.H. Dickson. 1979. "Mid-Flandrian changes in vegetation on Mainland Orkney." *New Phytologist* 82:585-612.

Keith-Lucas, M. 1986. "Neolithic impact on vegetation and subsequent vegetational development at the Scourd of Brouster." in *Scord of Brouster*. Edited by A. Whittle. Oxford: Oxford University Comittee for Archaeology Monograph No.9. pp.92-119.

King, F.B. 1977 "An evaluation of the pollen content of coprolites as environmental indicators." *Journal of the Arizona Academy of Science* 12: 47-52.

Knox, E.M. 1954. "Pollen analysis of a peat at Kingsteps Quarry, Nairn." *Transactions of the Botanical Society of Edinburgh* 36:224-229.

Knox, S.A. 1985. *The Making of the Shetland Landscape*. Edinburgh: John Donald Ltd.

Kryzwinski, K.S., Fjelldal and E.C. Soltveldt 1983. "Recent palaeoethnobotanical excavations at Bryggen, Bergen, Norway. " in *Site, Environment and Economy*. Edited by B. Proudfoot. BAR. International Series. p. 145-169.

Kuhry, P. 1985. "Transgression of a raised bog across a coversand ridge originially covered with an oak-lime forest." *Review of Palaeobotany and Palynology* 44:303-353.

Kummel, B and Raup, D. Editors 1965. *Handbook of Palaeontological Techniques*. San Fransisco: H.W. Freeman.

Kutzbach, J.E., and P.J. Guetter. 1986. "The influence of changing orbital parameters and surface boundary conditions on climate simulations for the past 18,000 years." *Journal of the Atmospheric Sciences* 43:1726-1759.

Kutzbach, J.E., Guetter, P.J., Behling, P.J. and Selin, R. 1993. "Simulated climatic changes: results of the COHMAP climate model experiments." in *Global Climates Since the Last Glacial Maximum*. Edited by H.E. Wright, J.E. Kutzbach, T. Webb, W.F. Ruddiman, F.A. Street-Perrot and P.J. Bartlein. Minneapolis: Minnesota University Press:24-93.

Lamb, H.H. 1977. *Climate, Past, Present and Future*. Volume 2: climate history and the future. Methuen and Co. Ltd.

Lamb, H.H. 1988. *Weather, Climate and Human Affairs.* London: Routledge.

Lamb, R.G. 1985 "Sumburgh: Prehistory under sand." in *Shetland Archaeology.* Edited by B. Smith. Lerwick: Shetland Times. pp.27-46.

Lewis, F.J. 1908. "The plant remains in the Scottish peat mosses, Part III." *Transactions of the Royal Society of Edinburgh* 46:33-69.

Lewis, F.J. 1911. "The plant remains in the Scottish peat mosses, Part IV." *Transactions of the Royal Society of Edinburgh* 47:793-833.

Lorente, M.A. 1986 *Palynology and Palynofacies of the Upper Tertiary in Venezuela.* Berlin: Cramer Dissertiones Botanicae.

Lowe, J.J. 1993. "Isolating the climatic factors in early and mid-Holocene palaeobotanical records from Scotland." in *Climate Change and Human Impact on the Landscape.* Edited by F.M. Chambers. London: Chapman Hall. pp.67-80.

Lundqvist, N. 1963 " *Tripterospora* s.lat. Pyrenomycetes." *Bot. Notiser.* 122: 589-603.

Lundqvist, N. 1972. "Nordic Sordariaceae s. lat." *Symbolae Botanicae Upsaliensis* 20:1-374.

MacHugh, D.E., C.S. Troy, F. McCormick, I. Olsaker, E. Eythorsdottir, D.G. Bradley 1999. "Early medieval cattle remains from a Scandinavian settlement in Dublin: Genetic analysis and comparison with extant breeds." *Philosophical Transactions of the Royal Society of London* .Series B-Biological Sciences. pp.111-119.

Macauley Institute for Soil Research. 1976. *Soil Survey of Scotland. Sheet 84 and Part 94. Nairn and Cromarty* .Aberdeen. 1:63 630.

Macauley Institute for Soil Research. 1982. *Soil Survey of Scotland. Sheet 1. Orkney and Shetland.* Aberdeen.

Mallik, A.U., Gimmingham, C.H. and Rahman, A.A. 1984. "Ecological effects of heather burning I. Water infiltration, moisture retention, and porosity of surface soil." *Journal of Ecology* 72:767-776.

Manum, S.B., K. Johnsen, and I. Throndsen. 1985. "Acid resistant components of organic matter in Upper Quaternary Skagerrak sediments." *Norsk Geologisk Tiddskrifft* 65:85-6.

Mayewski, P.A., P.C. Buckland, K.J. Edwards, L.D. Meeker and S. O'Brien. 1996. "Climate change events as seen in the Greenland ice core (GISP2): implications of the Mesolithic of Scotland." in *The Early Prehistory of Scotland.*

Edited by T. Pollard and A. Morrison. Edinburgh: University Press. pp.74-84.

McVean, D.N. and D.A. Ratcliffe. 1962. *Plant Communities of the Scottish Highlands*. Edinburgh: HMSO.

Mellars, P. 1976. "Fire ecology, animal populations and man: a study of some ecological relationships in prehistory." *Proceedings of the Prehistoric Society* 42:15-45.

Merritt, J.W. 1990. "The lithostratigraphy at Clava, Inverness-shire and a new model for the origin of its shell bearing deposits as glacially transported allocthons." in *Beauly to Nairn Field Guide*. Edited by C.A. Autonn and J.W. Merritt. Coventry: Quaternary Research Association. pp.24-40.

Middeldorp, A.A. 1982. "Pollen concentration as a basis for indirect dating and quantifying net organic and fungal production in a peat bog ecosystem." *Review of Palaeobotany and Palaeoecology* 37:225-282.

Moe, D. 1983. "Palynology of sheep's faeces: relationship between pollen content, diet and local pollen rain." *Grana* 22: 105-13.

Moore, J. 1996. "How to fire a major deciduous forest in an inclement climate." in *The Early Prehistory of Scotland*. Edited by T. Pollard and A. Morrison. Edinburgh: University Press. pp.62-74.

Moore, P.D. 1988 "The development of moorlands and upland mires." in *Archaeology and the Flora of the British Isles*. Edited by M. Jones. Oxford: Oxford University Commitee for Archaeology Monograph no. 14. pp.116-122.

Moore, P.D. and D.J. Bellamy 1974. *Peatlands*. London: Elek Science.

Moore, P.D., A.T. Evans, and M.T. Chater. 1986. "Palynological and stratigraphic evidence for hydrological changes in mires associated with human activit.," in *Anthropogenic Indicators in Pollen Diagrams*. Edited by K. E. Behre. Rotterdam: A.A. Balkema. pp.209-220.

Moore, P.D., J.A. Webb, and M.E. Collinson. 1991. *Pollen Analysis*. 2nd. edition. Oxford: Blackwell Scientific Publications.

Muller, J. 1959. "Palynology of recent Orinoco delta and shelf sediments." *Micropalaeontology* 5:1-32.

Munro , R. 1924. *Prehistoric Scotland*. Edinburgh: Wiliam Blackwood and Sons.

Mykura, W. 1976. *Orkney and Shetland. British Regional Geology*. Edinburgh: HMSO.

Nagel-de Boois, H.M., and E. Jansen. 1971. "The growth of fungal mycelium in forest soil layers." *Revue d'Ecologie et de Biologie du Sol* 8:109-520.

Noddle, B. 1986. "The animal bones (from Scord of Brouster)," in *Scord of Brouster*. Edited by A. Whittle. Oxford: Oxford University Committee for Archaeology. Monograph No. 9.

Odgaard, B.V. 1994. "The Holocene vegetation history of northern West Jutland, Denmark." *Opera Botanica* 123:1-171.

Ogden, E. C. 1974. "Identification of airborne fungal spores." in *Manual for Sampling Airborne Pollen*. Edited by E.C. Ogden, G.S. Raynor, J.V. Haynes, D.M. Lewis, and J.H. Haines. New York: Hafner Press. pp.141-190.

O'Sullivan, P.E. 1974a. "Two Flandrian pollen diagrams from the east central Highlands of Scotland." *Pollen et Spores* 16:33-57.

O'Sullivan, P.E. 1974b. "Radiocarbon dating and forest clearance on Speyside (east central Highlands of Scotland)." *Proceedings of the Prehistoric Society* 40:206-8.

O'Sullivan, P.E. 1976. "Pollen analysis and radiocarbon dating of a core from Loch Pityoulish, eastern Highlands of Scotland." *Journal of Biogeography* 3:293-302.

Owen, O. 1998. "From past to present at Kebister" in *The Shaping of Shetland*. Edited by V. Turner. Lerwick: The Shetland Times Ltd. pp.31-46.

Øvrevik, S. 1985. "The second millenium and after." in *The Prehistory of Orkney*. Edited by C. Renfrew. Edinburgh: Edinburgh University Press. pp.131-149.

Pals, J.P., B. van Geel, and A. Delfos 1980. "Palaeoecological studies in the Klokkeweel bog near Hoogkarspel (Prov. of Noord Holland, The Netherlands)" *Review of Palaeobotany and Palynology*. 38: 371-418

Parkinson, D. T.R.G. Gray and S.T. Williams. 1971. "Methods for studying the the ecology of soil microorganisms." *I.B.P. Handbook* no. 19. Oxford: Blackwell.

Parry, C.C., P.K. Whiteley, and R.D.H. Simpson. 1981. "Integration of palynological and sedimentological methods in facies analysis of the Brent formation." in *Petroleum Geology of the Continental Shelf of North West Europe*. Edited by L.V. Illing and G.D. Hobson. London: Institute of Petroleum. pp.205-215.

Peglar. S. 1979. "A radiocarbon-dated pollen diagram from Loch of Winless, Caithness, north-east Scotland." *New Phytologist* 82:245-263.

Pennington, W., E.Y. Haworth, A.P. Bonny and J.P. Lishman. 1972. "Lake sediments in northern Scotland." *Philosophical Transactions of the Royal Society of London* B 264:191-294.

Persson, T. 1994. *Information on Spore Tablets*. Department of Quaternary Geology, University of Lund.

Philips, T. 1994. *The Siting of the Clava Cairns*. Reading: University of Reading.

Piggott, S. 1956. "Excavations in passage graves and ring cairns of the Clava group, 1952-1953." *Proceedings of the Society of Antiquaries of Scotland*. 88:173-207.

Plant, J.A. 1968. *The Climate of the Coastal Region of the Moray Firth*. Climatological Memorandum No.62. Bracknell: Meterological Office.

Platt, M. 1956. "Report on the animal bones (from Jarlshof)." in *Excavations at Jarlshof, Shetland*. Edited by J.R.C. Hamilton. Edinburgh: HMSO. pp.99-105.

Pocock, A.J. 1981. "The classification of plant derived particulate organic matter in sedimentary rocks." in *Organic Maturation Studies and Fossil Fuel Exploration*. Edited by J. Brooks. London: Academic Press. pp.13-109.

Pocock, S.A.J 1982 "Identification and recording of particulate sedimentary organic matter." in *How to Assess Maturation and Palaeotemperatures*. S.E.P.M. short course No 7. p.13-132

Rackham, O. 1986. *The History of the Countryside*. London: J.M. Dent.

Renfrew, C. 1985. "Appendix Radiocarbon dates." in *The Prehistory of Orkney*. Edited by C. Renfrew. Edinburgh: Edinburgh University Press. pp.263-275.

Ritchie, A. 1995. *Prehistoric Orkney*. London: Batsford Ltd.

Ritchie, G. and A. Maclaren 1972. "Ring cairns and related monuments in Scotland." *Scottish Archaeological Forum* 4:1-17.

Robinson, D. 1987. "Investigations into the Aukhorn peat mounds, Keiss, Caithness: pollen, plant macrofossil and charcoal analysis." *New Phytologist* 106:185-200.

Round, F.E. 1973. *The Biology of the Algae*. London: Edward Arnold.

Round, F.E. 1981. *The Ecology of the Algae*. Cambridge: Cambridge University Press.

Schweingruber, F.H. 1990. *Ein Atlas zur Bestimmung europ: Fischer Baum-, Strauch-, und Zwergstrauchizer*. Bern: Verlag P. Haupt.

Scott, W. and R. Palmer. 1987. *The Flowering Plants and Ferns of the Shetland Islands*. Lerwick: The Shetland Times Ltd.

Simmons, I.G. 1975. "Towards an ecology of Mesolithic man in the uplands of Great Britain." *Journal of Archaeological Science* 2:1-15.

Simpson, D.A. 1996. "Excavation of a kerbed funerary monument at Stoneyfield, Raigmore, Inverness, Highland, 1972-3." *Proceedings of the Society of Antiquaries of Scotland* 126:53-86.

Simpson, I.A. and D.A. Davidson. 1995. *Palaeo-Landscapes of the Clava Cairns, Balnuaran of Clava, Invernesshire: Soil Micromorphological Evidence.* Unpublished Report, Department of Environmental Science, University of Stirling.

Simpson, I.A. and D.A. Davidson. 1997. *Palaeo-Landscapes of the Clava Cairns, Balnuaran of Clava, Invernesshire: Soil Micromorphological Evidence.* Unpublished Report, Department of Environmental Science, University of Stirling.

Smith, D.E. 1993a. "Burragarth." in *The Quaternary of Shetland*. Edited by J. Birnie, J. Gordon, K. Bennett, and A. Hall. London: Quaternary Research Association. pp.52-54.

Smith, D.E. 1993b. "Sullom Voe." in *The Quaternary of Shetland*. Edited by J. Birnie, J. Gordon, K. Bennett, and A. Hall. London: Quaternary Research Association. pp.56.

Söderstrom, B.E. 1975. "Vertical distribution of microfungi in a spruce forest soil in the south of Sweden." *Transactions of the British Mycological Society.* 65:419-425.

Söderstrom, B.E. 1977. "Vital staining of fungi in pure cultures and in soil flourescein diacetate." *Soil Biology and Biochemistry* 95:59-63.

Spence, D. 1979. *Shetland's Living Landscape*. Sandwick: The Thule Press.

Stace, C. 1995. *New Flora of the British Isles*. Cambridge: Cambridge University Press.

Stuiver, M. and Reimer, P.J. 1993. "Extended 14C database and revised CALIB radiocarbon calibration program." *Radiocarbon*. 35:215-230.

Tauber, H. 1965." Differential pollen dispersion and the interpretation of pollen diagrams." *Damarks Geologiske Undersøgelse* 11R 89:1-69.

Thomas, J. 1991. *Rethinking the Neolithic*. Cambridge: Cambridge University Press.

Tinsley, H.M. and R.T. Smith 1974. "Surface pollen studies across a woodland/heath transition and their application to the interpretation of pollen diagrams." *New Phytologist* 73:547-565.

Tipping, R. 1994. "The form and fate of Scotlands woodlands." *Proceedings of the Society of Antiquaries of Scotland* 124:1-54.

Tipping, R. 1996. "Microscopic charcoal records, inferred human activity and climate change in the Mesolithic of northernmost Scotland." in *The Early Prehistory of Scotland*. Edited by T. Pollard and A. Morrison. Edinburgh: Edinburgh University Press. pp.39-62.

Tipping, R., S. Carter, and D. Johnston. 1994. "Soil pollen and and soil micromorphological analyses of old ground surfaces on Biggar Common, Borders Region, Scotland." *Journal of Archaeological Sciences* 21:387-401.

Tipping ,R., D. Long., I.A. Simpson, D.D. Davidson and S. Carter. 1997. *Soil Pollen Analysis: Testing of Assumptions Employed in the Interpretation of Buried Soil Profiles*. unpublished report.

Tolonen, K. 1986. "Charred particle analysis." in *Handbook of Holocene Palaeoecology and Palaeohydrology*. Edited by B.E. Berglund. New York: Wiley-Interscience. pp.485-495.

Traverse, A. 1988. *Paleopalynology*. London: Unwin Hyman Ltd.

Turner, V. 1998a. *Ancient Shetland*. London: Batsford.

Turner, V. Editor. 1998b. *The Shaping of Shetland*. Lerwick: Shetland Times Ltd.

Tyldesley, E.B. 1973a. "Long range transmission of pollen to Shetland. I. Sampling and trajectories." *New Phytologist* 72:175-181.

Tyldesley, E.B. 1973b. "Long range transmission of pollen to Shetland. II. Calculation of pollen deposition." *New Phytologist* 72:183-190.

Tyldesley, E.B. 1973c. "Long range transmission of pollen to Shetland. III. Frequencies over the past hundred years." *New Phytologist* 72:691-697.

van den Hoek, D.G. Mann, and H.M. Jahns. 1995. *Algae: Introduction to Phycology*. Cambridge: Cambridge University Press.

van der Wiel, A.M. 1982. "A palaeoecological study of a section taken from the foot of the Hazendonk (Zuid-Holland, The Netherlands), based on the analysis of pollen, spores and macroscopic plant remains." *Review of Palaeobotany and Palynology* 25:1-120.

van Geel, B. 1978. "A palaeoecological study of Holocene peat bog sections

in Germany and the Nerherlands based on the analysis of pollen, spores and macro and microscopic remains of fungi, algae, cormophytes and animals." *Review of Palaeobotany and Palynology* 25:1-178.

van Geel, B. 1982. "A palaeoecological study of a Late Holocene section from 'Het Ilperveld' N. Eastern Netherlands." *Review of Palaeobotany and Palaeoecology* 36:95-161.

van Geel, B. 1986. "Application of Fungal and Algal Remains and other Microfossils in Palynological Analyses." in *Handbook of Holocene Palaeoecology and Palaeohydrology*. Edited by B.E. Berglund.London: John Wiley & Sons Ltd. pp.497-505.

van Geel, B., S.J.P. Bohnke, and H. Dee. 1981. "A palaeoecological study of an upper Late Glacial and Holocene sequence from 'De Borchert', The Netherlands." *Review of Palaeobotany and Palynology* 31:367-448.

van Geel, B., G.R. Coope, and T.V.D. Hammen. 1988. "Palaeoecology and stratigraphy of the late glacial type section at Usselo (the Netherlands)." *Review of Palaeobotany and Palynology* 60:25-129.

van Geel, B., D.P. Hallewas, and J.P. Pals. 1983. "A late Holocene deposit under the Westfriese Zeedijk near Enkhuizen (Prov of N-Holland, the Netherlands), palaeoecological and archaeological aspects." *Review of Palaeobotany and Palynology* 38:269-335.

van Geel, B., M.B. Jurjen, and J.P. Pals. 1983. "Archaeological and palaeoecological aspects of a medieval house terp in a reclaimed raised bog area in North Holland." *Berichten van de Riijkdienst voor het Oudheidkundig Bodemonderzoek* 33:419-444.

van Geel, B., L.R.Mur, M. Ralska-Jaziewiczowa, and T. Goslar. 1994. "Fossil akinetes of Aphanizomenon and Anabena as indicators for medieval phosphate- eutrophication of Lake Gosciaz (Central Poland)." *Review of Palaeobotany and Palaeoecology* 83:97-105.

van Smeerdijk, D.G. 1989. "A palaeoecological study of a peat profile from the Assendelver Polder (The Netherlands)" *Review of Palaeobotany and Palynology*58:231-288.

Vuorela, I. 1972. "Relative pollen rain around cultivated fields." *Acta Bottanica Fennica* 102:1-27.

Walker, M.J.C. 1984. "A pollen diagram from St. Kilda, Outer Hebrides, Scotland." *New Phytologist* 97:99-113.

Waterbolk, H.T. 1958. "Pollen spectra from Neolithic grave monuments in

the northern Netherlands." *Palaeohistoria* 5:39-51.

Watling, R. 1992. *The Fungus Flora of Shetland*. Edinburgh: Royal Botanic Garden, Edinburgh.

Watson, A. and R. Bradley. forthcoming. "The Clava Cairns and the pattern of settlement - the results of field survey, 1995-1997." in *The Good Stones: A new investigation of the Clava cairns*. Edited by R. Bradley. Edinburgh: Society of Antiquaries of Scotland Monograph series.

Welinder, S. 1983. "The ecology of long term change." *Acta Archaeologica* Lundensia series 8 minore no.9.

West, G.S., and F.E. Fritsch. 1927. *A Treatise on the British Freshwater Algae*. Cambridge: Cambridge University Press.

Whittington, G. 1980. "A sub-peat dyke on Shurton Hill, Mainland, Shetland." *Proceedings of the Society of Antiquaries of Scotland* 109:30-35.

Whittington, G. and E.J. Edwards. 1993. "Vegetation change on Papa Stour, Shetland, Scotland: a response to coastal evolution and human interference?" *The Holocene* 3:54-62.

Whittington, G. and K.J. Edwards. 1997. "Vegetation change," in *Scotland: Environment and Archaeology 8000 BC- AD 1000*. Edited by K.J. Edwards and I. Ralston. London: John Wiley & Sons. pp.63-83.

Whittington, G., K.J. Edwards, and P.R. Cundill. 1991. "Late and post glacial vegetational change at Black Loch, Fife, eastern Scotland- a multiple core approach." *Holocene* 118:147-166.

Whittle, A.W., M. Keith-Lucas, A. Milles, B. Noddle, S. Rees, and J.C.C. Romans. 1986. *Scord of Brouster*. Oxford: Oxford University Comittee for Archaeology Monograph No.9.

Wolf, F.A. 1966a. "Fungus spores in East African lake sediments." *Bulletin of the Torrey Botanical Club* 93:104-113.

Wolf, F.A. 1966b. "Fungus Spores in East African Lake Sediments. II." *The Journal of the Elisha Mitchell Scientific Society 82*:57-61.

Wolf, F.A. 1967. "Fungus spores in East African lake sediments. VI." *Journal of the Elisha Mitchell Scientific Soceity* 83:113-117.

Wolf, F.A. and S.S. Cavaliere. 1966. "Fungus spores in East African lake sediments. III." *Journal of the Elisha Mitchell Scientific Soceity* 82:149-154.

Wright, H.E. Jnr. 1966. "The use of surface samples in Quaternary pollen